


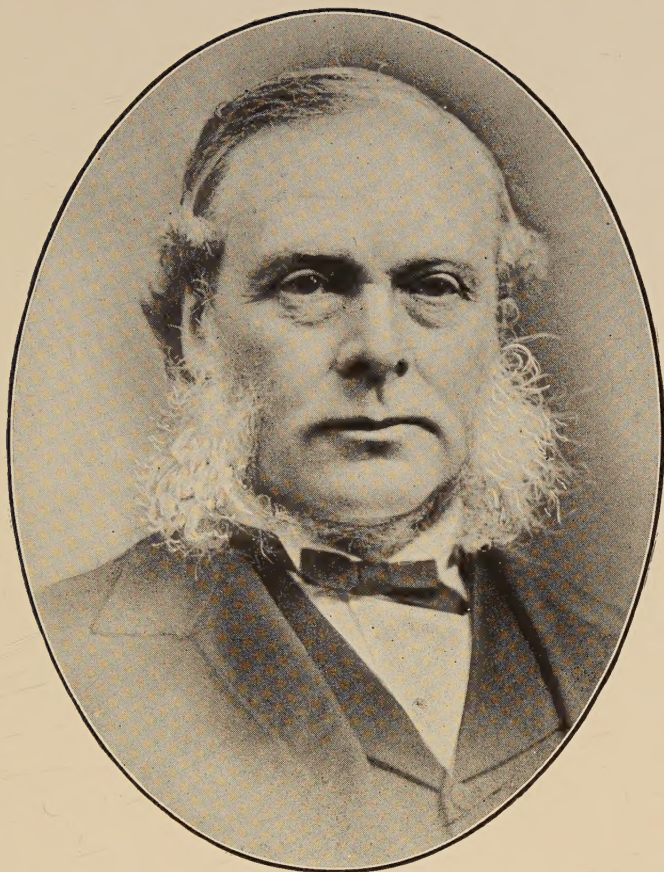
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LISTER
AND
THE LIGATURE

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Sir Joseph Lister

Born 1827

House Surgeon, Edinburgh, 1854

Professor of Surgery, Glasgow, 1860-1869

Professor of Clinical Surgery, Edinburgh, 1869-1877

Professor of Clinical Surgery, King's College, London, 1877-1893

Created Baronet, 1883

Elevated to the Peerage, 1897

Died 1912

LISTER
AND
THE LIGATURE

A LANDMARK IN THE HISTORY
OF MODERN SURGERY



COMPILED BY
THE RESEARCH READERS OF THE
SCIENTIFIC DEPARTMENT

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Preface

IT IS not the intention here to give a history of modern surgery, nor a history of one particular man or epoch. The workers in the Department, having lived through the years embraced in this survey, have simply gathered data covering the re-introduction and the re-birth of the surgical ligature and suture, which event forms an important part in the history of modern surgical technique.

With this event the name of Lister must ever be associated.

The history of the development of modern surgery is adorned and rendered brilliant, not by the genius of one man—it is the fruit of many of the world's choicest intellects. In Lister and the absorbable ligature we find a point in the swing of the pendulum.

Lister did not discover antiseptis, he did not discover the ligature, and he did not discover catgut, or introduce it into surgery. He crudely formulated a system and a method which, through its aftermath, revolutionized surgery.

As Schimmelbusch well said, "Even though the weapons we now employ are different from those which were first chosen, and although later times may bring newer and better methods, we will always be indebted to him who first showed us the way in which we are advancing, and there will always appear before us in the most brilliant light the name of Joseph Lister."

The story of Lister's efforts to produce a catgut ligature as here told, is mainly from his own writings, now scattered and inaccessible.

"The amount of knowledge which one age, or certainly one man, can add to the common store, is small.

"What we call truth is only the hypothesis which is found to work the best. In reviewing the opinions and practises of other ages and generations, we shall do well to look upon their errors as inevitable slips made in the search for truth, and to give them the benefits of that indulgence which we ourselves will one day stand in need of."

Fraser's "Golden Bough."

THE LIGATURE

BEFORE LISTER

IN an historic search, when we have arrived at the first written records, we find that we have only a history of something that was known ages before.

The oldest medical writings, the Egyptian papyri, are the records in medicine and surgery of something that was known centuries prior thereto. Esculapius and Hippocrates, the so-called "Fathers" of the healing art, introduced nothing new; their story only points back to centuries before their time.

Steps toward surgical cleanliness are very old. Hippocrates used boiled water for irrigation, and prescribed that "the hands and nails of the operator should be clean."

The twisting of a cord was one of the earliest of arts. Made from linen or other fibres, from animal skins, sinews and intestines, they were used for sewing, tying, mending, and for musical instruments. The savage and the nomad developed a healing art, including a rude surgery. He had at hand a bone needle, a cord of fibre or animal tissue, with which to stop the flow of blood or mend a wound, and undoubtedly he used them for this purpose.

The catgut suture is the evolution of the musical string. The strings of the old Greek harps were made from the twisted intestines of sheep and other animals. The strings from the harp and the violin appear in the records of surgery through the ages. The Arabian Rhazes (900 A.D.) specifically describes the stitching of wounds with a thread made from the intestines of sheep. In the next century, Albucasis sutured with a thread made from the intestines of sheep. Celsus, in the first century A.D., describes the ligature as of ancient origin. The renowned Galen, second century A.D., used hemp and silk cord for ligating, but when unable to obtain it he recommended catgut (*graciliu chordaru*).

A famous classic painting represents the epoch-making barber-surgeon, Ambrose Paré (1510-90), as "introducing the ligature into surgery." Before his time the use of the ligature as a means of controlling hemorrhage was common. His progressive step was to apply the ligature instead of the cautery or boiling water in amputations.

Nor was the absorbable suture unknown. Sir Astley Cooper, "England's most popular surgeon," ligated vessels with absorbable sutures (1808). Dr. Physick of Philadelphia (1806) and Dr. Jameson of Baltimore (1827) used buckskin and kidskin ligatures.

We are accustomed to regard the ligature and suture as modern inventions. The fact is that ligatures and sutures of absorbable and non-absorbable material appear in the history of the surgical art over and over again. Dropping out of use for long periods, they reappear when some one reinvents them once more.

"It seems hard to understand how so useful an auxiliary to the surgeon as the ligature (it seems indispensable to us), could possibly be allowed to go out of use or even be forgotten. It will not be difficult, however, for any one who recalls the conditions that obtained in old-time surgery to understand the cause.

"The ligature is a most satisfying immediate resource in stopping bleeding from an artery, but a septic ligature inevitably causes suppuration and almost inevitably leads to secondary hemorrhage. In the old days of septic surgery secondary hemorrhage was the surgeon's greatest and most dreaded bane. Sometime from the fifth to the ninth day a septic ligature came away under such conditions that inflammatory disturbance had prevented sealing of the vessel. If the vessel was large, then the hemorrhage was fast and furious, and the patient died in a few minutes.

"After a surgeon had had a few deaths of this kind he dreaded the ligature. He abandoned its use and took kindly to such methods as the actual cautery, red hot knives for

amputations, and the like, that would sear the surfaces of tissues and the blood vessels, and not give rise to secondary hemorrhage. A little later, however, some one not familiar with secondary risks would reinvent the ligature. If he were cleanly in his methods and, above all, if he were doing his work in a new hospital, the ligature worked very well for a while. If not, it soon fell into innocuous desuetude again.”—Puschmann: “Handbuch der Geschichte der Medizin,” Vol. 1, page 652 (1905).

IN THE TIME OF LISTER

“In the nineteenth century the advancement of science was organized, and scientific surgery was created.”—Garrison.

In the later decades of this century came Lister, and it was during this period that antiseptic methods were formulated, and the catgut ligature rehabilitated.

The events seem to run somewhat in this wise: Joseph Lister, of English birth (afterward Lord Lister), educated as a physician, in 1860 became Professor of Surgery in the University of Glasgow. He had been well grounded in science.

Bacteriology was without a name or a place (the name was first recorded in 1884).

“But the idea of micro-organic infection of wounds had long existed. Heister, at least twenty-five years prior, had distinctly stated, ‘No germs, no pus.’ Lister, himself, acknowledged that to Pasteur he was indebted for the principles that were the foundation of his antiseptic system; that his use of carbolic acid came from Lemaire. Just as one generation builds upon the successes of another, Lister’s work was not the result of a discovery, but rather of an inheritance.”—Buchanan.

“As an operator, Lister was not brilliant, but deliberate and careful. His severe and austere ideals were not the traits that make for rapid and showy success. His progress was

slow; he left no school. When his body was laid to rest in Westminster, England buried her greatest surgeon."—Garrison.

From the father of his wife, Syme, Lister learned to use silver wire sutures, drainage, and likewise the importance of frequent change of dressings and scrupulous cleanliness.

Marcy gives a pen picture of surgical operators of the period, "who operated in a Prince Albert coat, well buttoned at the front, and stiff with dried blood of many a previous operation over its sleeves and front. Assistants copied the master, with the addition of well waxed ligatures adorning their buttonholes. It was quite the custom in threading the needle to follow the mode of the housewife, by putting the thread in the mouth before inserting in the eye of the needle."

Lister became imbued with the idea that "while the atmosphere was chief carrier of germ life, infectious material might and did pertain to the many and varied substances with which man was constantly in contact. It was this latter fact that led him to give attention to the ligature which was to be imbedded in the wound."—Buchanan.

"The demonstration of the use of catgut forms one of the most brilliant chapters in Lister's contribution to surgery.

"He first used silk dipped in melted wax, in which carbolic acid had been incorporated. His first real contribution to wound treatment was the ligation of all bleeding vessels with carbolized catgut, cut short and left deep in the wound. His studies had shown that the catgut surrounding the blood vessel was slowly absorbed and disappeared without suppuration.

"Lister closed all his wounds with through and through stitches. It remained for others to demonstrate that sutures as well as ligatures could be buried."—Marcy.

In America, Lister's efforts received scant attention. He read a paper on the "Antiseptic Method" before the International Medical Congress at Philadelphia (1876). The reception which this paper received was anything but enthu-



THE LISTER STEAM SPRAY APPARATUS. Intended to produce an "antiseptic atmosphere" surrounding the field of operation. Steam generated by an alcohol lamp. Carbolic acid 1-40 contained in the jar on the left, vaporized. The notorious spray was finally abandoned by Lister himself.

This picture represents an apparatus made after Lister's own pattern, which is now in possession of the Janway Library, College of Physicians and Surgeons, New York.

siastic. In the literature of the period, Lister's theory was classed by foremost surgeons as "an arrogant pretension." "The germ theory furnishes a very unstable foundation for a system of wound treatment. One cannot believe that bacteria are the cause of suppuration."

A few venturesome spirits visited London and the Continent, and adopted the idea and the methods.

In the United States the Listerian dressings of "antiseptic putty," oil and pitch gauze, were abrogated for the more cleanly types of moist and dry dressings. The carbolic spray and irrigator were in use for only a short period.

"With some operators Listerism was a fetish. Routine was practised with the exactitude of a church ritual service. Orders of procedure were written down, and if by accident any deviation took place, it was the rule to begin all over again.

"One enthusiastic follower of Lister so flushed his patient and operating table with antiseptic solutions that he was compelled to wear rubber boots."—Buchanan.

Iodoform was shaken from a sprinkler over wounds and dressings, until the air and clothing of operators, attendants and visitors were redolent with the rank and nauseating fumes.

AFTER LISTER

The years immediately following Lister's promulgation of his ideas form an interesting bit of history. The medical journals of the period are filled with contributions dealing with every phase of Listerism and wound infection.

In England he was bitterly assailed, not only as to methods, but as to results. "Even his personality was ridiculed and attacked. His bitterest antagonists were among his own countrymen. He was accused of 'humbuggery,' 'bug catching,' 'pickling wounds in carbolic acid.'" Some of his opponents went so far as to accuse him of "fraud, lying and wilful suppression of statistics." It was fully twenty years before the surgeons of his own country in any measure accepted his ideas.

"Lister's opponents entirely missed the fundamental facts underlying the germ theory and Lister's antiseptic method, viz., that infection in all its various forms was always of bacterial origin—a wholly novel and momentous idea."—Kean.

The Continental surgeons, especially those of Germany and France, however, at once took over Lister's theories, applied and extended them. The Germans added to Lister's carbolic a long list of antiseptics, including corrosive sublimate and the "skunk of surgery"—iodoform.

The literature of that period, and since that time, is overflowing with discussions of ligatures and sutures. Every material of the nature of cord or thread appears, disappears and reappears. Gold, silver and iron wire, silk, silkworm gut, linen and cotton cord; tendons from a host of animals, including the ox, the kangaroo, the rat, whale, raccoon; the intestinal tissue of many and varied creatures; catgut, flooded and impregnated with every chemical known in the list—iodine, mercury, iodoform, thymol, silver, carbolic acid and anilin dyes; it was hardened with formaldehyde, tannin, chromic acid; it was heated, boiled and baked; the gut was immersed in volatile oils, in chloroform, alcohol, turpentine and ether, with a long et cetera. A writer compiled a list of upwards of three hundred formulas for treating catgut, without reaching the end.

Lister, in later years, frankly admitted that "the appliances which I first used for carrying out the antiseptic principles were rude and needlessly complicated." The years that have since passed have witnessed great improvement in all respects.

In regard to catgut, however, Lister never receded from having his strands immersed in carbolic acid.

Somewhat in contrast to the ideas of Lister's time as to suture material, is the definition of Neef in "Guiding Principles in Surgical Practice" (1914):

"The prime qualities of suture material, as it is required in plastic surgery, are:

- a* Sterility
- b* Definite and measured absorbability
- c* Fineness, with adequate tensile strength
- d* Pliability.

Even at the present day there is no vegetable fibre, animal or synthetic product, which answers all these requirements quite as well as the suture prepared from catgut."

But that some of the problems as to suture material remain unsolved is evident from an article in the London "Lancet," August 23, 1924:

"With the introduction of catgut it was thought the problem had at last been solved, but it was soon found that the difficulty of controlling the rate of absorption was considerable. However careful the catgut may be prepared, individual variation in the absorptive powers is enormous, and apart from the variation of suture material, we have to consider the endurance of the material sutured. It is well that we should recognize that the only permanent suture, if it is ever discovered, is one that is gradually embodied in the living tissues. Unless this condition is found, no suture, whatever its absorbability, can hold the soft tissues together for more than a few days."

Out of the welter, slowly, at times again with rapidity, there arose the modern system of asepsis, sterilized dressings, and all the elements that go to make up the surgical progress of these days.

Concurrently with surgical progress have come improved surgical appliances—instruments of precision, apparatus evolved from thorough application of the sciences to the needs of the surgeon. A simple but most striking example, as stated in the "Medical Record," is the "aseptic absorbable ligature and suture material evolved on the basis of Listerian principles, and now produced under practically ideal conditions. This has been the means of a twofold end of surgical progress in general, and of the improved aseptic vascular suture in particular."

The advances in vascular surgery through the aid of an absorbable aseptic suture as cited by Garrison ("History of Medicine") include—

- 1877—Venous suture (portal vein): Eck, Pavloff
- 1881—End-to-end suture veins: Hirsch
- 1881-1892—Arterial sutures: Schede, Dorfler, Murphy
- 1892—Catgut rings for intestinal suturing: Abbe
- 1896—Circular suture femoral artery: Murphy
- 1897—End-to-end sutures blood vessels: Murphy
- 1898—U-suture of carotid artery: Jaboulay, Briaud
- 1900—Triangular suture (blood vessel) and transplantation: Carrel
- 1902—Intrasaccular suturing: Matas

For this progress writers have not hesitated to acknowledge surgery's indebtedness to the labors of Lister.

The great French surgeon Championniere pointed out that asepsis, the Listerian ideal, must be preceded by antisepsis, and that heat sterilization is in the truest sense antiseptic.

"The surgeons of the future will improve upon the procedures of the present, but the making and maintaining of an aseptic wound must ever be based upon the fundamental principles enunciated by the late immortal scientist, Lord Lister."—Marcy.

"The modern ligature, the aseptic or antiseptic ligature, must be accredited to Lister. His researches and his labors laid the foundation of one of the greatest blessings ever given to mankind—clean surgery. His methods are no longer used, but his idea is the basis of all ligature preparations to-day, i.e., to produce one that will not cause suppuration. A study of the various endeavors that have been made throughout the world during the past thirty years to obtain a perfect ligature (and the end is not yet), not only demonstrates how painstaking are those who have to deal with the care of wounds, but also shows that a satisfactory ligature has not yet been obtained."—A. D. Whiting, 1907.

The contrast between the time of Lister and forty years later is tersely summed up in the "British Medical Journal" of February 24, 1912:

"What Lister accomplished is perhaps best shown by the fact that so late as the mid 70's, Sir John Erickson stated in a public address that 'operative surgery had at that time reached its finality; there were stated regions in the human body into which the surgeon could not penetrate—the brain, the chest, the abdomen.' "

All these secret chambers of the "House of Life" have long since been brought within the province of surgery, and these enormous advances of the healing art have been made possible by the work of Lister, and that work will continue to make practicable further extension to a degree we can only temporarily surmise.

Vast as is the realm of modern surgery, it may be stated with Rossetti that "leagues beyond these leagues there is more sea."

In the development of a science, and particularly of medicine and surgery, a generation may be responsible for a revolution of its theories and its methods.

This is well expressed by a writer:

"Glancing hastily over the period that has elapsed since Lister, on the whole we can see that humanity has been the gainer through the abolition of inflammation, suppuration, secondary hemorrhage, blood poisoning, gangrene and erysipelas, as sequels of accidents and operations; by the relief from suffering and death; by operations formerly thought impossible; by rendering amputations and compound fractures safe and simple instead of deadly.

"We have witnessed a wonderful growth of hospitals with elaborate equipment, laboratories and adjuncts. We have witnessed the creation of surgical specialists. We have seen the evolution of a new vocation—the great order of nursing. Surely as we view the enormous progress of modern surgery as a result of bacteriology and antisepsis and the concomitant

asepsis, we glow with enthusiasm at what one profession has been able to accomplish in a single generation."—W. S. Wile.

Many will join with Bayard, America's ambassador, speaking at the Royal Society's Lister Jubilee, and exclaim, "My Lord, it is not a profession, it is not a nation, it is humanity itself which, with uncovered head, salutes you!"

*Extracts from the Writings of Joseph Baron Lister
Relating to the Ligature*

OBSERVATIONS ON LIGATURE OF ARTERIES ON THE ANTISEPTIC SYSTEM (*Lancet*, 1869, Vol. I, p. 451. Corrected February, 1870)

Finding somewhat uncertain results in the use of silk for ligatures, Lister turned his attention to animal material. In so doing he reinstated the long before rejected and condemned animal intestines. His research mind was exhibited in that his first specimen was made by himself from the intestine of an ox. In the first tie the gut broke at the knot.

"Various attempts have been made, both in the early part of the century and more recently, to improve the ligature, or to supersede it by other methods. Nevertheless, for obstructing the calibre of an arterial trunk in its continuity, no means hitherto devised have proved superior to a small silk thread tied in a secure knot, with the ends left projecting from the wound. Yet, as is implied by the numerous efforts at improvement, the ligature in this form is far from perfect. The internal and middle coats are ruptured by the constricting noose, while a portion of the tough external coat is pinched together and deprived of its vitality. The dead tissue, becoming contaminated by the putrefaction which occurs in the interstices of the silk fibres, acts, together with the septic ligature, as a cause of irritation to the neighbouring parts of the arterial wall, which consequently degenerate into an imperfect structure, inadequate to withstand the powerful cardiac impulse; and even before the slough separates by suppuration, the blood breaks through the feeble barrier, unless it be fortified by a firm plug of internal coagulum. Hence, if a considerable branch takes origin close to the part tied, the formation of a clot being prevented by the current of blood, secondary haemorrhage is the inevitable consequence; and thus the ligature is inapplicable in situations otherwise eligible for it, such as the femoral artery near Poupart's ligament, the origins and endings of the iliacs and the innominate.

"Even when the thread is distant from any considerable branch, the terrible risk of haemorrhage cannot be said to be altogether absent. The degenerate structure of the vessel near the ligature, unlike the arterial wall in its normal condition, is

prone to ulceration, and the organizing coagulum is similarly circumstanced; so that an unhealthy state of the wound may open up the calibre of an artery tied in the most favourable situation.¹

"Again, when the parts about the vessel communicate with loose cellular interspaces in important regions, as is the case with the iliac arteries or the subclavian, diffuse suppuration is frequently a cause of death. Finally, the cure is always rendered tedious by the time required for the separation of the ligature; while the presence of an external wound during the period thus protracted involves a risk, by no means inconsiderable in some localities, of hospital gangrene or erysipelas.

"The Antiseptic System, however, places this branch of surgery, like most others, in a new light. One point which it has brought out in striking relief is, that a portion of dead tissue is not necessarily thrown off by suppuration, but, unless altered by putrefaction or artificially imbued with stimulating salts, serves as pabulum for the surrounding living parts, which remove it by a sure process of absorption. Hence, the death of a portion of the external coat included in the ligature does not of itself render it a cause of suppuration. And I conceived that if a silk thread, steeped in some liquid capable of destroying the septic organisms in its interstices, were tied round an artery, and left with short-cut ends in a wound dressed antiseptically,² the foreign body, soon losing, by diffusion into the

¹ It has been long since noticed that haemorrhage occurs more frequently from the distal than from the cardiac end of the vessel. This seems at first sight contrary to what might be expected, since the cardiac end is subjected to much greater strain. The explanation is, I believe, afforded by some facts which I had occasion some years ago to point out. (See the Croonian, Lecture "On the Coagulation of the Blood," printed in vol. i, p. 109.) It was then shown that a perfectly undisturbed coagulum resembles healthy living tissue in failing to induce coagulation in blood near it; but that, on the other hand, while a clot is, from its softness, peculiarly liable to laceration and other disturbance, a disturbed coagulum acts like injured tissue in impressing upon neighbouring blood a coagulating tendency. Hence, when a ligature has been tied round an artery, although a minute clot necessarily forms upon the injured internal and middle coats, it would undergo no increase if the blood in the vessel were absolutely quiescent. But the pulsations of the artery operate as a disturbing cause to the clot already formed, which consequently increases in proportion to the degree of the disturbance; and as this is much greater at the cardiac side, the clot grows more quickly there, and forms a more secure barrier against the pressure of the blood.

² In using the expression "dressed antiseptically," I do not mean merely "dressed with an antiseptic," but "dressed so as to ensure absence of putrefaction."

circulation, the stimulating salt with which it was saturated at the outset, and being in its own substance as unstimulating chemically as a pellet of lead from a fowling-piece, would either remain, like the latter, permanently encapsuled, or itself experience absorption together with the dead tissue in its grasp. In either case, being destitute of irritating properties, it should leave the primitive strength of the arterial coats unimpaired; when the objection to tying near a large branch would cease to exist. The wound meanwhile would, under proper management, close rapidly, without any deep-seated suppuration, and would be efficiently protected against the evil influences of impure atmosphere. In short, the ligature of an arterial trunk in its continuity would be brought to a state of perfection.

"I have subjected these theoretical views to the test of experience; and though the results have not turned out in all respects exactly as I had anticipated, yet those finally arrived at appearing satisfactory, I now present to the profession an account of all that I have done in the subject.

"Case of Ligature of the External Iliac Artery on the Antiseptic System.—On the 29th of January, 1868, I was requested by Dr. Fergus to see a lady fifty-one years of age, who was suffering from an inguinal aneurysm which had existed for four years, but had of late been markedly on the increase, causing agonizing pain, which had confined her to bed for the last four weeks, and had considerably reduced her strength. The aneurysm was of the size of a large orange, affecting the uppermost part of the left femoral artery, and extending a little above Poupart's ligament. Any delay appearing undesirable, I tied the external iliac on the following day, in presence of Dr. Fergus, and assisted by Messrs. Hector Cameron, Appleton, and James Coats. There was nothing peculiar in the operation, except that the incision was made a little further outward than usual, in order to avoid the upper part of the aneurysm. The only bleeding vessel that required attention was twisted. The ligature employed had been previously steeped for two hours in strong fluid carbolic acid, prepared by adding a small proportion of water to the crystals. The tightly twisted thread requires a considerable period of immersion to ensure thorough soaking with the liquid; and the acid does not impair the tenacity of the fibre.

"At the time of the operation, the superfluous acid was removed by transferring the silk to a solution of carbolic acid in thirty

parts of water; and the same lotion was used for the sponges, and also for washing the aneurysm-needle before it was passed round the vessel. The artery having been tied, and the ends of the ligature cut short, the wound was freely treated with the watery solution, some of which was poured in, to make sure that it penetrated to every part. The edges of the skin were then brought together with silver sutures, except in the middle, where I introduced a pledget of lint steeped in a solution of the acid in five parts of olive-oil, passing it deeply, but leaving one end projecting externally, to serve as a drain for blood and serum. I then applied an external antiseptic dressing, the details of which I need not now describe. The pledget of lint was cautiously withdrawn on the following day, under cover of a pretty large piece of lint imbued with the antiseptic oil; and the external dressing was reapplied, and afterwards changed at intervals proportioned to the diminution of the serous discharge, which, at the end of a fortnight, was estimated at about three minims in three days. At this time, some portions of lint, which had been left till then undisturbed, were removed, when the wound was found quite free from pus, being perfectly cicatrized where the sutures were introduced; while the central part, where the pledget was placed after the operation, presented the appearance of a superficial sore, but not a granulating one; for the deep surface of the dressing, being devoid of stimulating properties, had failed to induce granulation in the tissues on which it lay. Meanwhile the patient had been relieved from the pain which she previously suffered, without experiencing febrile disturbance or any material inconvenience from the operation, except uneasiness in the wound the first two days, during retching occasioned by the chloroform. The tongue had been natural throughout; the pulse had only on one day been as high as 90, 72 to 84 being the usual rates; and her appetite, which had been absent during the four weeks of agony that preceded the operation, returned two days after it, as soon as the derangement of the stomach from chloroform subsided. On the fourteenth day, as I was arranging her pillows, she sat upright without inconvenience. Four weeks after the operation, the wound being completely cicatrized, she was allowed to move about in her room; and, just six weeks from the date of the ligature of the artery, she descended three long flights of stairs, walked for some time in the streets, and reascended the steps to her lodgings; and, though fatigued by the effort, she felt next

day all the better for it. On the 31st of March, she called to see me, much improved in strength, though with still some tendency to swelling of the legs, especially the left, when in the erect posture. The aneurysmal swelling felt merely like a slight glandular thickening. On the 25th of July, 1868, I again visited her. She had derived much benefit from a stay at the seaside, and the tendency to oedema of the extremities was greatly diminished. There was still absence of pulsation in the external iliac artery, and the cicatrix remained quite sound twenty-five weeks after the operation.

"She continued for about ten months in fair health and strength; but, in the latter part of November, she became affected with a peculiar spasmodic disorder of the respiration, and on the morning of the 30th of the month, while sitting up in bed, she suddenly exclaimed that something had given way within her, and that she was dying, and then immediately expired. Next day I made a post mortem examination, when the idea which she had expressed proved correct—an aneurysm of the descending part of the arch of the aorta having given way, and discharged an enormous quantity of blood into the mediastinal and subpleural cellular tissue. The parts concerned in the operation having been removed and dissected, the following appearances were disclosed.

"The aneurysm was not entirely obliterated, but remained about the size of a cherry or large filbert, of somewhat fusiform shape. The upper two-thirds were solid, being occupied by firm coagulum incorporated with the sac. The lower third, situated just at the bifurcation of the common femoral, had been kept free from coagulation by the regurgitant stream of blood from the profunda into the superficial trunk. This part of the sac appeared constituted by the wall of the vessel, very slightly distended. The external iliac artery was considerably shrunk throughout, and tapered from each end to near the middle, where it was only about a twentieth of an inch in diameter. In the greater part of its length the structure of the dwindled vessel could be distinctly recognized, with adherent coagula in the interior, decolourized and otherwise altered. But at the narrowest part the artery was reduced to mere fibrous tissue, constituting a dense white band five-eighths of an inch long, from the middle of which was seen projecting at one side a round, buff-coloured appendage about a line in diameter, somewhat obscured by a trifling amount of inflammatory condensation of texture in the immediate vicinity. On scratching this little body with the point of a knife, I

found it to be very thin-walled capsule, containing the knot of the ligature, with two tapering ends, which were shorter than the thread was cut at the operation, while the noose had vanished altogether. The surface of the knot also showed clear indications of having been subjected to an eroding agency, similar, no doubt, to that exerted by granulations upon dead bone absorbed by them. Besides the remnant of the ligature, the tiny capsule contained a minute quantity of yellowish, semi-fluid material, looking to the naked eye like very thick pus. Under the microscope, however, pus-corpuscles were seen to form but a small proportion of its constituents, which were principally rounded corpuscles of smaller size, and fibro-plastic corpuscles, together with some imperfect fibres and granular material. In addition to these elements were some which at first puzzled me, but which turned out to be fragments of silk fibre, of various lengths, and of jagged, tapering, or otherwise irregular forms, and many of them greatly reduced in thickness, contrasting strongly with the uniform bands of a fresh piece of silk from the same reel that had furnished the ligature (Fig. 1).

"Mingled with the puriform fluid were also some delicate filaments of silk, visible without the microscope; and these seemed to retain their natural elasticity. Nor was there anything about the more minute pieces into which the fibres had been so strangely chopped up, to indicate that they were undergoing a process of solution or softening by the fluid that soaked the thread. They had rather the appearance of having been superficially nibbled, so to speak; confirming the impression conveyed by the naked-eye characters of the knot, that the silk had been eroded by the absorbing action of the surrounding parts. Indeed, considering the organic origin of silk, the remarkable thing seems to be, not that it should be absorbed by the living tissues, but that it should resist their influence so long.

"Why it was that the parts in immediate contact with the silk should have assumed so imperfect a structure is a difficult question, but one of great interest; because, although that structure could not be called pus, it was certainly a very near approach to it; and it is impossible to say that we had not here an incipient abscess. There can be no doubt that the presence of the thread was in some way or other the cause, and I think we can hardly be wrong in assuming that, in order to give rise to such degeneration of tissue, it must have operated as a persistent, if trifling, source of abnormal stimulation. Now, as

putrefaction is here out of the question, and as the substance of silk is not chemically stimulating, we seem shut up to the conclusion that the thread must have occasioned disturbance of a

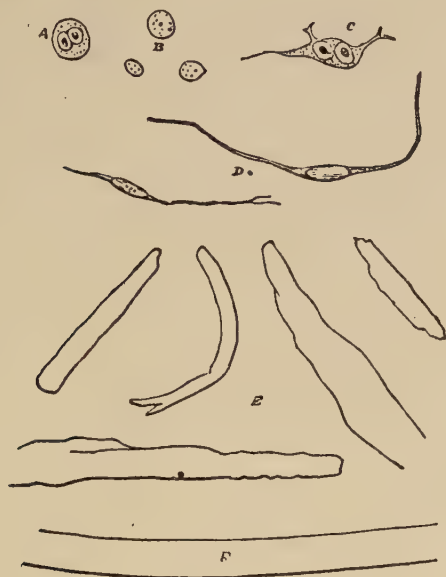


FIG. 1.—Constituents of the incipient abscess around the remains of the silk ligature. From a camera-lucida sketch. *A*, a pus corpuscle; *B*, rounded corpuscles of smaller size; *C*, fibro-plastic corpuscle with endogenous cell-development; *D*, ordinary fibro-plastic corpuscles; *E*, irregular fragments of silk fibre partially absorbed; *F*, a piece of fresh silk fibre introduced for comparison.

mechanical nature. Further, the effect in question seems to be essentially connected with the disintegration of the silk. For in the horse's carotid the silk ligature, having remained unaltered during the six weeks that had passed after the operation, was found surrounded on all sides by compact tissue; and in the present case, so long a period as ten months having elapsed before the puriform condition was observed in an apparently incipient stage, it is probable that the thread had lain for a long time inert, producing irritation only when partially absorbed. If, then, we inquire how the disintegrating silk could prove a source of mechanical irritation, it seems not improbable that it may have been from the sharp and jagged

fragments of the fibre perpetually fretting the elements of the living tissue around them.

"This view, if correct, would explain the curious fact observed by Lawrence and others, that when fine silk ligatures had been left with short-cut ends in a stump, though the wound might heal without their separation in the first instance, they were liable to make their appearance subsequently, sometimes at so late a period as seems to exclude the idea of putrefaction having occurred from organisms introduced into the threads. Indeed, such ligatures occasionally showed themselves encapsuled in little nodules in the cicatrix, without suppuration occurring at all. In other words, the apparently soft silk, instead of remaining, like a smooth leaden pellet, permanently embedded in the place where it was first introduced, made its way to the surface with or without suppuration, like a sharp spiculum of rigid glass; the silk being in its minute structure comparable to the pellet when in the primitive condition of smooth continuous fibres, and to glass spicula when in the form of jagged fragments as the result of partial absorption.

"But whatever may be thought of this explanation, it is clear that if there is any chance of silk, though used antiseptically, giving rise, even in exceptional cases, to abscess in the vicinity of an artery tied with it, this is a serious objection to its employment; and as the near approach to suppuration in the present instance was undoubtedly occasioned by the persistent presence of the thread, the case, while interesting as affording evidence that silk is susceptible of absorption, suggests the expediency of substituting for that material some other substance which can be more readily taken up by the tissues.

"The use of 'animal ligatures,' of catgut, leather, or tendon, was long since tried and abandoned as unsatisfactory; but after the experience which the antiseptic system has afforded of the disappearance, without suppuration, of large dead pieces of skin and other textures, there could be little doubt that threads of animal tissue, if applied antiseptically, would be similarly disposed of.

"And even if chemical processes should have been used in preparing such threads, it did not seem likely that this would interfere with their absorption; for I knew that the free action of carbolic acid on blood and sloughs had no such deterring influence, and I have long been satisfied that the injection of

a strong solution of perchloride of iron or tannic acid for the cure of naevi produces subcutaneous sloughs, which are imbued with the ingredients injected, and yet disappear, as a rule, without the formation of pus.

"In order to put the antiseptic animal ligature fairly to the test, I made the following experiment:—

"Ligature of the Carotid Artery in the Calf on the Antiseptic System, with Threads composed of Animal Tissue.—On the 31st of December, 1868, I tied the right carotid artery about the middle of the neck in a healthy calf a few days old, the animal being under chloroform. Ligatures of two different kinds were employed, at an interval of about an inch and a half, the sheath of the vessel being left undisturbed in the intervening part. The cardiac ligature was of home manufacture, composed of three strips of peritoneum from the small intestine of an ox, firmly twisted together into a three-fold cord. The distal thread was of fine catgut, called 'minikin gut' by the London makers. Both had been soaked for four hours in a saturated watery solution of carbolic acid, which swelled and softened them, so that the thread of my own making was too large to enter the eye of the aneurysm-needle except near the ends, where it was thinner than elsewhere. This substantial ligature bore the strain of tying well, but the fine catgut broke as I tightened the noose. I did not, however, remove it, but having a second piece at my disposal, passed it round at the same place, and with gentle traction completed the knot. There were thus two ligatures of the fine gut at the distal site. All were cut short, except one end of the catgut, which I purposely left about three-quarters of an inch long, to give a better opportunity of ascertaining what would become of the foreign material.

"The antiseptic arrangements were as follows: Before the operation the hair of the part was cut short, and a solution of carbolic acid in four parts of linseed oil (preferred for its cheapness) was rubbed well into the skin, to destroy any putrefactive organisms lying amongst the roots of the hairs; for any so situated might escape the action of the external antiseptic dressing, and communicate putrefaction to the discharges, and thence to the interior of the wound. The sponges used in the operation were wrung out of a watery solution of the acid (1 to 40), and all the instruments introduced into the wound, together with the fingers of my left hand and the copper wire used for sutures, were treated with the same lotion, some

of which was poured into the wound after the introduction of the last stitch, at one of the intervals left for the escape of discharge, to make sure against the chance of any fresh blood which had oozed out during the process of stitching having regurgitated and taken living germs in with it. The external dressing was a towel saturated with the oily solution, folded as broad as the length of the neck, round which it was wrapped so as to extend freely beyond the wound in all directions, prevented from slipping backward and forward by being stitched to a halter round the head, and to a girth behind the forelegs, while a bandage rolled round it kept it applied accurately to the surface. A sheet of gutta-percha tissue, to prevent contamination of the antiseptic towel from without, and another roller, completed the dressing; and a 'cradle' was placed upon the neck to check lateral movements which might disturb it. The dressings were left untouched for three days, and then entirely removed.

"The wound was found quite dry and free from tenderness, and the cloth showed only a superficial bloody stain. The stitches being taken out, a drop of pus escaped from the track of the suture next the head; but this was the only appearance of suppuration in the case from first to last, and on the separation of the scab, a few days later, a sound cicatrix was disclosed. A month (thirty days) after the operation the animal, which had continued in perfect health, was killed, and the soft parts of the neck below the spine were removed for examination. On dissection I was struck with the entire absence of inflammatory thickening in the vicinity of the vessel, the cellular tissue being of perfectly normal softness and laxity. On exposing the artery itself, however, I was at first much disappointed to see the ligatures still there to all appearance as large as ever. But had I borne in mind what I had observed in some of my earlier cases of compound fracture treated antiseptically, I should have been prepared to find these threads present in appearance, though absent in reality.

"It may be well for me to quote from the account I have before given of one of these cases. It was a compound fracture of the leg, produced by direct violence, with a wound of considerable size, and a great deal of extravasation of blood into the limb. In accordance with the practice which I then followed, a piece of lint soaked with undiluted carbolic acid had been placed over the wound, and had formed

with the blood a firm crust. 'Nearly three weeks after the accident I was detaching a portion of the adherent crust from the surface of the vascular structure into which the extravasated blood beneath had been converted by the process of organization, when I exposed a little spherical cavity about as big as a pea, containing brown serum, forming a sort of pocket in the living tissues, which, when scraped with the edge of a knife, bled even at the very margin of the cavity. This appearance showed that the deeper portions of the crust itself had been converted into living tissue. For cavities formed during the process of

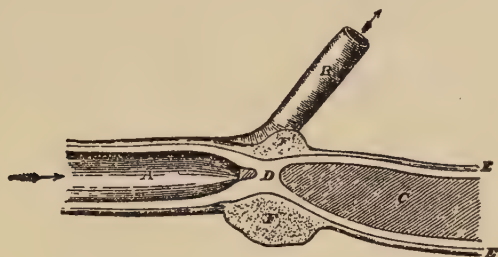


FIG. 2.—The vessel seen in longitudinal section, magnified. From a camera-lucida sketch. *A*, the artery to the cardiac side of the ligature, kept free from clot by the stream of blood through the branch *B*. *C*, the coagulum filling the artery to the distal side of the ligature, *F, F*, *D*, the middle and internal coats, somewhat thickened and blended together within the grasp of the ligature. *E*, the external coat continuous in structure with the organized ligature.

aggregation, like those with clear liquid contents in a Gruyère cheese, occur in the grumous mass which results from the action of carbolic acid upon blood; and that which I had exposed had evidently been one of these, though its walls were now alive and vascular.' Thus the dead, but nutritious mass, had served as a mould for the formation of new tissue, the growing elements of which had replaced the materials absorbed, so as to constitute a living solid of the same form.

"Hence it might have been anticipated that the ligatures of peritoneum and catgut placed on the calf's carotid would, after the expiration of a month, be found transformed into bands of living tissue. Such was, in truth, the case, as was apparent on closer examination. They had, indeed, a deceptive resemblance to their former condition, from the persistence in their substance of the impurities of the original materials, the dark

adventitious particles being of mineral nature incapable of absorption, so that they had remained as a sort of tattooing of the new structure. Nevertheless, a marked alteration in colour had taken place, especially in the distal ligature, where the dirty grey of the softened catgut had changed to a dirty pink tint. The two pieces of catgut which had been tied round the vessel at that part had become, as it were, fused together into a single fleshy band, inseparably blended with the external coat of the artery. The knots were nowhere discoverable, and the only indication of the end which had been left long at the time of the operation was the presence of a black speck here and there upon a delicate thread of cellular tissue in connexion with the vessel. The cardiac ligature was in like manner continuous in structure with the arterial wall. The short ends had disappeared; but the massive knot was represented by a soft smooth lump, which appeared at first entirely homogeneous, except that it was speckled with dark particles, as before referred to. On section, however, I discovered in the interior of the mass, and lying close to the wall of the artery, a small residual portion of the original knot, of comparatively firm consistence, and with the three-fold twisted character of the cord plainly visible. It was quite distinct from the living tissue that surrounded it, so that it could be readily picked out from its bed with a pair of needles. A slender and irregular remnant of the noose was also found lying in a sort of tubular cavity, extending about half round the vessel.

"Thus the process of organization had not yet quite invaded the entire thickness of the foreign solid, and it was a happy circumstance that the thread had been so constructed that the distinction between the old structure and the new could be plainly recognized.

"Ample as was the evidence afforded to the naked eye of the organization of these ligatures, it was satisfactory to find it confirmed in the clearest manner by the microscope. A bit of the residue of the peritoneal thread, having been teased out with needles in a drop of water, presented, like a fresh piece of peritoneum, the wavy bundles of parallel fibres characteristic of perfectly developed fibrous tissue. Adhering to the surface of the remnant of the ligature was some soft opaque material, readily washed off with water, consisting of corpuscles of different forms, most of them caudate or fibro-plastic, but some spherical, though not resembling those of pus; and here and

there fragments of the original peritoneal tissue, affected more or less with interstitial cell-development. At a short distance from the remains of the old thread, the fleshy material which had been formed at its expense proved to be a most beautiful example of fibro-plastic structure, the coarse fibres which mainly



FIG. 3.—Some of the elements of the fibro-plastic structure of the organized peritoneal ligature at the knot. From a camera-lucida sketch.

constituted it being composed of very large elongated cells, often containing several nuclei, and presenting in their course branchings and thickenings of various forms, as represented in the sketch (Fig. 3). Here and there were some fibres more perfectly formed, and also cells of a more rudimentary character.

“Again, the band which had resulted from the organization of the two fine threads of catgut, which, from the smallness of their bulk, had no doubt vanished early, having had longer time to perfect its structure, was a comparatively well-developed form of fibrous tissue, consisting of coarse fibres rather than of elongated cells, being thus intermediate between the merely

fibro-plastic material of more recent growth and the completed texture of the original thread. For it is to be remarked that a piece of catgut exhibits under the microscope abundance of perfect fibrous tissue. A more favourable period for the investigation, with a view to establishing the nature of the change which ligatures of animal tissue experience under antiseptic management, could hardly have been selected.

"Between the parts tied the calibre of the artery was occupied by adherent coagulum, which was for the most part decolourized, and exhibited under the microscope fibro-plastic cells of irregular forms. A similar clot was present between the distal ligature and a small branch that arose about a quarter of an inch beyond it. But between the proximal ligature and the heart the formation of a coagulum had been entirely prevented by a large vessel taking origin immediately above the part tied, which had thus borne for a month the full brunt of the cardiac impulse. Yet the vessel, so far from showing any sign of giving way, as it would inevitably have done had it been tied in such a situation without antiseptic precautions, appeared to have derived additional strength from the operation. The encircling ring of new tissue incorporated with the arterial wall must have had a corroborative effect; and within its grasp the inner coats, which seemed to have been but imperfectly ruptured by the soft and substantial ligature, were considerably thickened, and had coalesced so as to form a strong cul-de-sac, the irregularities of which had been smoothed over by a little fibrinous deposit, which had assumed the characters of a firm fibrous tissue, and presented a free surface undistinguishable from that of the lining membrane of the artery (Fig. 2).

"At the situation of the distal ligature the structure of the vessel seemed entirely unaffected. The middle coat was seen in longitudinal section as a pink streak between two white lines, representing the external and internal tunics, neither thicker nor thinner than in neighbouring parts. The catgut threads had been tied too gently to produce rupture of the internal and middle layers, and their presence and the constriction which they occasioned, whatever may have been their effect in the first instance, had left no permanent marks of disturbance, while the fleshy band that had replaced them, though in time it would doubtless have dwindled down to an insignificant filament, was at least a temporary addition to the strength of the artery.

"These appearances at the distal ligature are calculated to revive under a new aspect the old question whether it would not be better always to avoid rupture of the internal and middle coats, which could easily be done by using a pretty thick piece of catgut softened by steeping it in a watery solution of carbolic acid. In this way the wall of the vessel would be left from first to last entirely intact. This, however, is probably a matter of indifference. Indeed, judging from the condition of the artery at the cardiac ligature, the injury done to the vessel at the outset by tight tying seems to lead to changes which increase its power of resistance, which was certainly severely tested in the present instance.

"It appears, then, that by applying a ligature of animal tissue antiseptically upon an artery, whether tightly or gently, we virtually surround it with a ring of living tissue, and strengthen the vessel where we obstruct it. The surgeon, therefore, may now tie an arterial trunk in its continuity close to a large branch, secure alike against secondary haemorrhage and deep-seated suppuration—provided always that he has so studied the principles of the antiseptic system, and so carefully considered the details of the mode of dressing best adapted to the particular case in hand, that he can feel certain of avoiding putrefaction in the wound. For my own part, I should now, without hesitation, undertake ligature of the innominate, believing that it would prove a very safe procedure.

"Catgut, manufactured from the small intestine of the sheep,¹ may be had at a low price, from the thickness of a horsehair upwards. As sold in the shops, however, it is quite unfit for the purposes of the surgeon. For, when moistened with water or with the animal fluids, it becomes not only very soft and weak, but as slippery as a piece of recent intestine, so that a knot tied upon it yields to the slightest traction.

"But it is a happy circumstance that a simple process of preparation deprives it of these objectionable qualities. For this purpose, no method which I have yet tried answers better than that which I happened to use first of all for rendering the gut antiseptic—viz., suspending it in a mixture of five parts of some fixed oil (e.g., olive or linseed) with one part of carbolic acid liquefied by adding five per cent. of water to the crystals. Part of the water associated with the acid is disengaged by the oil, pro-

¹ I need hardly remark that catgut is of a totally different nature from so-called silkworm's gut, which is in reality unspun silk.

ducing a very fine emulsion, which effects a remarkable physical change in the animal tissue. At first the gut is rendered swollen, soft, and opaque, though not to so great an extent as if placed in simple water; but in the course of a few days the opposite change begins to show itself, and the thread becomes gradually firmer and more transparent, till, after the lapse of a few weeks, it is quite free from opacity, and very strong, though supple. If drawn through the fingers, it is no longer slippery, but has a crisp feel like a thread of india-rubber, and a knot tied upon it holds more securely than one on waxed silk. Water, whether cold or at a temperature of 100° Fahr., has now little effect upon the thread, and even putrid serum of blood acting upon it for days at the temperature of the body does not make the knots relax their hold. In this form the gut seems almost a perfect material for the ligature under any circumstances in which it is required.

“‘Prepared catgut’ will, I hope, soon become a well-known article of commerce. But, for the sake of surgeons who may wish to prepare it for themselves, it is necessary to mention, in order to avoid disappointment, that the essence of the process is the action of an emulsion of water and oil upon the animal tissue. The same effect is produced upon the gut, though more slowly, by an emulsion formed by shaking up simple olive oil and water, as by one which contains carbolic acid. On the other hand, an oily solution of carbolic acid without water has no effect upon the gut beyond making it antiseptic, and if water be added only in the small proportion which the acid enables the oil to dissolve, though the gut is rendered supple, and acquires a dark tint from the colouring matter of the oil, it will be found, even after steeping for months in such a solution, that when transferred to water it swells up and becomes soft, opaque, and slippery, as if it had not been subjected to any preparation. How it is that an emulsion produces this remarkable change in the molecular constitution of the tissue I do not profess to understand. I was at first inclined to regard it as a closer aggregation of the particles, brought about by a kind of slow drying of the moistened gut in the oil, as the watery particles precipitate to the bottom of the vessel; but, not to mention other circumstances opposed to this view, the oil remains turbid for a very long time, the finer particles of water being extremely slow in precipitating, and if, after the lapse of weeks, a piece of dry unprepared gut is suspended in

it, the thread is soon rendered soft and opaque by the very liquid in which gut which has been longer immersed is growing constantly finer and more transparent.

"It is necessary that the gut be kept suspended so as not to touch the bottom of the vessel, for any parts dipping into the layer of precipitated water would fail to undergo the change desired. The vessel containing the emulsion should be left undisturbed, for if the water is shaken up with the oil the process is retarded. An elevated temperature of about 100° Fahr. seems for a while to promote the change, but ultimately leaves the gut in an unsatisfactory state compared with that obtained at an ordinary temperature. And conversely some portions of gut which I have prepared lately (February, 1870) in a room without a fire, in cold weather, at a temperature of about 46°, were in one week already in a trustworthy condition for surgical purposes. Hence the gut should be prepared in as cool a place as possible. The longer it is kept in the emulsion, the better the gut becomes. I once feared that it might in time grow too rigid for convenience, and possibly brittle also; but experience shows that this is not the case.

"When removed from the emulsion it soon dries in the air, but retains a considerable portion of its carbolic acid for several hours, so that no apprehension need be entertained of loss of its antiseptic property from exposure during the performance of an operation. In course of time it loses all the carbolic acid also, but retains permanently its altered molecular condition. If thus kept dry, as may prove the most convenient for the manufacturer on a large scale, it must be steeped thoroughly in some antiseptic lotion before it is used. And for the surgeon the most convenient way will probably be to keep it always in the antiseptic emulsion, so as to be ready for use whenever it is required.

"For tying an arterial trunk in its continuity, catgut at least as thick as common purse-silk will be found best. But for ordinary wounds, where, if one ligature happens to break, another can be easily applied, much finer kinds may be employed, and are convenient from their smaller bulk. Several yards of fine gut may be carried in the pocket-case, on a winder contained in a little oil-tight silver capsule which I have had constructed for the purpose, as an appendage to a caustic-holder."

AN ADDRESS ON THE ANTISEPTIC SYSTEM OF TREATMENT IN SURGERY, DELIVERED BEFORE THE MEDICO-CHIRURGICAL SOCIETY OF GLASGOW (*British Medical Journal*, 1868, Vol. II, pp. 53, 101, 461, 515; 1869, Vol. I, p. 301)

A two-hour-long extempore address, afterwards re-written from the newspaper reports, again covering the fundamental principles of the system.

The "antiseptic putty" had been replaced by a "lac plaster," a mixture of shellac and carbolic acid coated with gutta percha.

Here he exhibited his famous flasks containing urine, which had been sterilized by boiling. The necks of three of the flasks had been bent, but left open to admit free access of air; in the fourth flask the neck was left straight and open. In the three tubes with bent necks air had had free access to the putrescible fluid for six months at room temperature, and remained unchanged. The contents of the fourth tube (which had admitted air and dust particles) had putrefied.

A dramatic and striking demonstration against the theory of spontaneous demonstration, a staggering blow against the idea that the gases of the air were the cause of fermentation! A convincing proof of the germ theory of putrefaction.

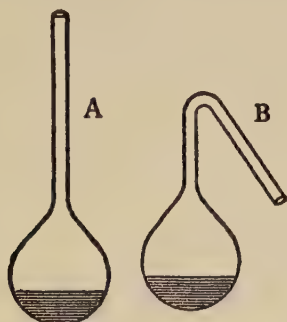
These flasks were carried about and exhibited for upwards of ten years, the contents retaining their clearness.

In this address he described his experiments with the carbolized ligature:

Ligature of Arteries

"I have now to show you a preparation illustrating the effects of the application of a ligature upon an artery on the antiseptic system. The theory of such a procedure is simple. A foreign body introduced among the tissues does not exert any disturbing influence upon them, unless it be either mechanically or chemically irritating. Thus, it is well known that a needle or a spiculum of glass may lie for an indefinite period embedded in the living textures without inducing suppuration; and any irritation which may result is due simply to the rigidity and form of the foreign solid. Now, a bit of silk or linen thread being composed of materials of soft consistence and as unstimulating chemically as glass or steel, its presence among the tissues cannot of itself occasion any disturbance. But, unlike the glass or metal, the thread is porous, and contains in its

interstices putrefactive germs, which, developing in the serum that bathes the ligature, give rise to the acrid products of decomposition, and these, in their turn, stimulate the surrounding tissues to granulation and suppuration. If, however, the thread were steeped in some liquid calculated to destroy the life of the germs in its interstices, and the wound by which it was



Lister's flasks containing sterilized urine. Flask A, with straight neck, admitting air and dust, putrefied; flask B, bent neck, admitting air but no dust, remained unchanged.

introduced were dressed antiseptically, the ends of the ligature being cut short, it might be left with confidence that its presence would not interfere with primary union, or occasion any disorder in the surrounding parts. [The traction exercised on the external coat by the noose of the ligature is no doubt a temporary cause of mechanical irritation, but this does not appear to have any considerable influence.] Before applying these principles upon the human subject, I thought it right to test them on one of the lower animals.

"Ligature of the Carotid Artery in the Horse, on the Antiseptic System.—On the 12th of December last, I tied the left carotid of a horse about the middle of the neck, using fine but strong 'purse-silk,' unwaxed, but steeped for some time in a saturated watery solution of carbolic acid. [The product of the action of carbolic acid upon blood serves the purpose of wax in preventing the first half of the knot from slipping during the tying of the second half.] The ligature having been tightly tied, so as to rupture the internal and middle coats, its ends were cut short, and the wound was freely treated with carbolic acid dissolved in forty parts of water. Seven stitches of the coarse soft wire used by veterinary surgeons for the purpose were introduced into the long wound, the most dependent part being

left free for the escape of discharge. The hair around the wound was well rubbed with a solution of carbolic acid in four parts of olive oil, and cloths saturated with the same antiseptic oil were applied overlapping the surrounding skin freely, and retained in position by means which I need not describe; and similar oil was poured daily upon the cloths for the first six days. Ten days after the operation I removed the dressings, and found the wound perfectly united throughout, except at the part purposely left open, which was covered with a sort of cheesy material, and as each stitch was removed there was absence of even serous exudation. The wound was now left exposed, and in three days more the lower part had healed by scabbing, no suppuration having occurred from first to last. At the same time, there was none of the swelling and induration that usually attend the application of a ligature to a vessel in the horse's neck, and the animal showed no signs of uneasiness when the part was freely handled.

"Five weeks and four days after the tying of the artery, the creature, though it had improved greatly in condition under its superior diet in the veterinary establishment, died, as the groom believed, of exhaustion from struggling ineffectually to rise from the recumbent posture. I had thus an opportunity of inspecting the parts concerned in the operation, some of which are now before you. In the first place, here is a portion of the skin containing the scar; and you will observe that it is a perfectly sound linear cicatrix, barely traceable among the hair. Here is the artery, slit up to show the condition of the interior. At the cardiac side of the place where the ligature was applied there was, as you see, an adherent coagulum, an inch and a quarter in length. But at the distal side there was no adherent clot, doubtless in consequence of the circulation through a large branch, about as big as the human vertebral, which came off, you will observe, as close to the situation of the ligature as was possible.

"The cul-de-sac formed by the distal end, though it showed indications of the puckering of the divided internal and middle coats, was completely cicatrized, the smooth lining membrane of the artery being continuous over the irregular surface. Why it was that the immediate vicinity of so large a branch did not lead to secondary haemorrhage, was clear from the state of things beside the ligature, which lay embedded in a firm fibrous structure, with not only no pus, but no granulations, no soften-

ing of tissue around it. The portion of the external coat included in the noose, though doubtless killed by the violence with which it was pinched, had not been thrown off as a slough, but, being unstimulating, because undecomposing, it had been absorbed and reproduced by the living parts near it; while the thread had been bridged over externally by dense fibrous tissue, so that the vessel showed but little appearance of constriction where it had been tied, and it appears to be as strong at this part as at any other. You may form some estimate of its strength from the manner in which it resists the traction to which I now subject it. Here is the ligature with its short cut ends, apparently unchanged, except that it was divided in my search for it in its fibrous bed.

"This case confirms the hope I ventured to express at the meeting of the British Medical Association in Dublin last autumn, that the antiseptic system would free the deligation of a large artery in its continuity of the two essential elements of danger to which it is now liable, viz., an unhealthy condition of the wound, and secondary haemorrhage. Thus encouraged, I felt justified in carrying a similar practice into human surgery.

"The success of these cases of ligature depends, as we have seen, upon the circumstance that not only a neutral foreign body, but a portion of dead tissue, if simply protected from putrefaction, is entirely devoid of irritating properties. A good example of this fact is presented by a case at present under my care.

"Catgut, manufactured from the small intestine of the sheep, may be had at a very low price, from the thickness of a horsehair upwards. In the dry state, it is somewhat objectionable from its rigidity, and also from a tendency of the first half of the knot to slip before the second half is secured. Water renders it perfectly supple, and as little liable to slip as waxed silk. But if a watery solution of carbolic acid be used for the purpose of making it antiseptic, the protracted immersion requisite to ensure completeness of the effect makes the finer kinds too weak, and the stouter too clumsy, so that it will not enter the eye of an ordinary aneurysm-needle. The method which I have found to answer best is to keep the catgut steeping in a solution of carbolic acid in five parts of olive oil, with a very small quantity of water diffused through it. A larger proportion of the acid would impair the tenacity of the thread. If a mere oily solution be employed, the gut remains rigid, the oil not entering at all

into its substance. But a very small quantity of water, such as the acid enables the oil to dissolve, renders the gut supple, without making it materially weaker or thicker. And, curiously enough, the presence of this small amount of water in the oily solution gradually brings about a change in the gut, indicated by a deep brown colour, after which it may be placed in a watery solution for a long time without swelling, as a portion prepared in a simple oily solution does. This is a great convenience. For an oily solution is unpleasant to work with during an operation; and exposure to the air soon renders gut suppled with water rigid from drying. But, when it has been treated in the way above recommended, it may be transferred to a watery solution at the commencement of an operation, and so kept supple without having its strength or thickness altered.

"For tying an arterial trunk in its continuity, catgut as thick when dry as ordinary purse-silk will be found best; but for ordinary wounds, where, if one ligature happen to break, another can be easily applied, much finer kinds may be employed, and are convenient from their smaller bulk. For every-day use, a small oil-tight capsule may be carried in the pocket-case; and this case can be replenished from a larger stock as may be necessary. I have had a small silver bottle with well-fitting screwed top adapted to my caustic case; and this contains two little rods of wood with gut of two sizes wound upon them, together with a few drops of the antiseptic oil: and now that torsion has almost entirely superseded the ligature in ordinary wounds, this small supply will probably last me for months.

"I hardly need remark that catgut is of a totally different nature from the so-called silkworm gut, which is in reality unspun silk."

ON THE ANTISEPTIC PRINCIPLE IN THE PRACTICE OF SURGERY.

A PAPER READ BEFORE THE BRITISH MEDICAL ASSOCIATION
IN DUBLIN, ON AUGUST 9, 1867 (*British Medical Journal*,
1867, Vol. II, p. 246)

This paper emphasized the principles as distinct from the methods. It is the second public paper devoted to the Listerian theory. In the interval between the two papers, his first dressing, the crust of blood and carbolic acid, had been displaced by antiseptic putty.

This paper records the change from the long ligatures, hanging out of the wound, so long in use, to the method of cutting the ends short.

"I have found that when the antiseptic treatment is efficiently conducted, ligatures may be safely cut short and left to be disposed of by absorption or otherwise. Should this particular branch of the subject yield all that it promises, should it turn out on further trial that when the knot is applied on the antiseptic principle, we may calculate as securely as if it were absent on the occurrence of healing without any deep-seated suppuration, the deligation of main arteries in their continuity will be deprived of the two dangers that now attend it—namely, those of secondary haemorrhage and an unhealthy state of the wound. Further, it seems not unlikely that the present objection to tying an artery in the immediate vicinity of a large branch may be done away with; and that even the innominate, which has lately been the subject of an ingenious experiment by one of the Dublin surgeons on account of its well-known fatality under the ligature from secondary haemorrhage, may cease to have this unhappy character, when the tissues in the vicinity of the thread, instead of becoming softened through the influence of an irritating decomposing substance, are left at liberty to consolidate firmly near an unoffending though foreign body."

METHOD OF ANTISEPTIC TREATMENT APPLICABLE TO WOUNDED SOLDIERS IN THE PRESENT WAR (*British Medical Journal*, 1870, Vol. II, p. 243)

The surging tide of battle in the Franco-Prussian War brought forth a host of English and American medical volunteers. Lister's aid was sought. He offered carbolic acid as an effectual weapon in the surgical armamentarium. It was found to be impracticable.

In the World War (1914) writers called attention to the backward swing to antiseptics. Godlee states that the problem of caring for infected war wounds still awaits solution; that "the influence of those scientific men whose genius is devoted to devising engines of death, has more than counter-balanced the efforts directed toward the saving of life."

In respect to the ligature, Lister said:

"Tie any bleeding vessels with properly prepared antiseptic catgut, cutting off the ends of the thread near the knot. If the surgeon does not possess this article, the arteries should, if possible, be secured by torsion; but for the sake of cases in which a ligature would be absolutely indispensable, some silk or linen thread should be kept steeping in a strong oily solution of carbolic acid, or, if very fine silk be used, it may be rendered antiseptic by steeping for a few minutes in the watery solution. When silk or linen is employed, the ends of the ligatures should be left projecting at the wound.

"Gunshot-wounds should not be stitched; but, where sutures are required, silk, steeped in oily solution of carbolic acid, will answer sufficiently well. After the introduction of the last stitch, distend the wound once more with the watery solution, by means of the syringe, and then continue the dressing, as in the text."

THE ADDRESS IN SURGERY DELIVERED ON AUGUST 10, 1871, TO
THE THIRTY-NINTH ANNUAL MEETING OF THE BRITISH
MEDICAL ASSOCIATION HELD IN PLYMOUTH (*British Medical
Journal*, 1871, Vol. II, p. 225)

Beginning the day before, continuing until three in the morning of the day of delivery, Lister labored in the preparation of this address, which covered the theory of his antiseptic treatment and exhibition of the means and mode of employing antiseptics.

As he spoke ligatures, dressings and paraphernalia covered the table in front of him, and assistants pumped the carbolic spray over a choking audience.

His references to the ligature and catgut were in part as follows:

"The antiseptic catgut ligature is used for securing the arteries while the spray still plays over the wound. It is absolutely necessary that it should be properly prepared. I must not enter into the method of preparation, further than to say that catgut undergoes a remarkable change in its physical constitution when steeped for a long time in an emulsion of water and oil, so that it becomes quite transparent, and no longer liable to become soft and slippery when placed in water or in a watery discharge. But for this circumstance, the animal ligature would be an impossibility; but, if you use it properly prepared, you will, I believe, see good reason to be satisfied with it. That which I now show is extremely fine, much finer

than any silk commonly employed; and yet with a piece like this I should not hesitate to tie the femoral artery in a stump. If you choose to use it thicker for a large vessel, you can do so. It is conveniently carried on a little winder, in a capsule appended to a caustic-case. The catgut, as tied in the ordinary reef-knot with the ends cut short, seems to me to be a perfect haemostatic. It has all the simplicity and universal applicability of the ligature, with, at the same time, the virtual absence of any foreign body from the wound. If putrefaction be avoided, it is rapidly absorbed, and you may reckon as certainly on the absence of any interference with primary union on the part of such ligatures, as if there were no ligatures at all. Should putrefaction occur, I was at first uneasy lest the prepared catgut might soften and permit haemorrhage. I was, therefore, at the pains to test some of the prepared catgut in the following manner.

"I tied some pieces of it at intervals round a cylinder of india-rubber, so as to pinch the india-rubber to a considerable degree of constriction, and then introduced it into putrid serum of blood, and kept it for a week at a temperature of about 90°. At the end of this period the india-rubber was still constricted, showing that the catgut had retained its hold in the putrid liquid, in spite of the constant strain of the elastic material upon the knots. No doubt, in such parts of a wound as actually putrefy, the little bits of catgut must come away like shreds or sloughs of cellular tissue; but I am bound to add that this is only a matter of presumption: for, although I have used nothing but this ligature for securing vessels in wounds for more than two years, excepting torsion, which I comparatively rarely resort to, and though in certain classes of cases putrefaction cannot be avoided, in no instance have I seen the catgut knot come away, nor have I ever known secondary haemorrhage or abscess caused by its use.

"Ligature of arteries in their continuity presents one of the most striking illustrations of the advantages of antiseptic treatment. I have only had two opportunities, since I published on the subject, for applying the catgut in this way; both of them were cases of popliteal aneurysm, and both were formidable from having become diffuse. One of them was in a man aged forty-seven, who had only noticed the aneurysm for five weeks, during which time it had been rapidly on the increase, so that the patient observed a change in its dimensions every day. On

his admission into hospital, on the 31st of August, 1869, it reached from the upper part of the ham to the top of the lower third of the femur. At the same time it caused extreme pain, with numbness in the limb, and the knee was bent at a right angle. I tied the femoral artery at once with a stout piece of prepared catgut, cutting the ends close to the knot, and the result was that within ten days the wound was a superficial sore bridged over with cicatrix, which afterwards healed like an ordinary narrow ulcer. There was a remarkable contrast in one particular in the treatment of this case compared with ordinary cases. Instead of leaving the patient to lie with his limb constantly in one position on a pillow until the time should have elapsed for the ligature to separate by suppuration—there being no separation to take place, and as I believed, no source of irritation present—I from the first began free movement of the limb, and at a very early period got the knee extended, to the very great advantage of the patient. I remembered a precisely similar case in which I tied the vessel with silk in the ordinary way some years ago, where the patient was not able to straighten the knee for weeks after leaving the hospital; and in fact I do not know that he is able to do so now.

“The other case was much more remarkable. The patient presented himself at the hospital with an aneurysm grown to enormous dimensions laterally, and extending up to the junction of the middle and upper thirds of the thigh. At the same time, partly from hæmorrhage into its own body, and partly from being worn out with the pain he endured, he was reduced to an extreme degree. In his case, also, the knee was flexed; there was much numbness and oedema in the foot, and no pulsation in either tibial artery. Under such circumstances, what was to be done? To open into this enormous mass by the old operation would be most unpromising. To amputate would, I felt sure, be to kill the man outright. The only alternative was to tie the artery. Considering the extent to which the huge mass had already interfered with the circulation, it seemed extremely probable that such a procedure would be followed by gangrene. Still it seemed to afford the only chance. Then the next question was, Where should it be tied? The lower down, the further from the heart, the better, if it could be safely done. But was there any choice? Was not the external iliac the only practicable site? The only part remaining in the thigh was what I believe is rightly regarded as a forbidden

region, from the vicinity of the profunda or other considerable branches. Yet having ascertained, by experiment, that an anti-septic catgut ligature does not weaken the artery at all, and does not make secondary haemorrhage likely to occur under such circumstances, I felt justified in putting on the ligature in this forbidden region.

"It is an extremely striking fact, if we think of it, that after a large arterial trunk has been tied, we never have haemorrhage on the second or third or fourth day—never practically during the first week, we may say. The external coat, pinched in by the ligature, is always strong enough to resist the impetus of the blood, however near the ligature may be to a branch, till the tissue has undergone alteration, till it has become softened by the granulating process through the irritating influence of the septic ligature. But if the ligature be not septic, nor in any other respect irritating, there is nothing to weaken the external coat. Why should it be weakened? On the contrary, as experiment has shown in one instance, the catgut itself, becoming replaced by living tissue, acts as a strengthening ring instead of making the vessel weaker. Hence I felt justified in applying it as near as possible to the aneurysmal tumour, though this was just about the most frequent place of origin of the profunda. Catgut a good deal thicker than that which I have shown was used, the ends being of course cut short, and all went well. There was no appearance of suppuration from the vicinity of the ligature, and the enormous mass gradually became absorbed. Being much emaciated, the man put on fat so fast that we were deceived at first with respect to the diminution of the coagulated blood, which was actually going on much more rapidly than we inferred from our measurements. Ultimately all that great mass disappeared, and the patient, first hobbling with crutches, then walking with a stick, is now a hale man.

"I have hitherto felt some hesitation in publishing cases of this kind, lest I should lead my professional brethren to do that which would only end in disaster. An eminent London surgeon wrote to me some time ago asking for catgut, as he wished to use it for tying the external iliac. I wrote back to him saying that if he did not feel sure he could avoid putrefaction in the wound, I would not advise him to use catgut, because, if the wound should putrefy, the catgut lying there, without any means of withdrawing it, would perhaps lead to unhealthy

ulceration and so occasion secondary haemorrhage. But with the spray I feel that, in operations of this sort, safety is a matter of certainty.

"The catgut ligature has other applications of interest. One was a ventral hernia in a young woman. It was of large size, and I laid the sac freely open so as to expose the adherent intestines and omentum which it contained, and separated the adhesions under the comparatively inconvenient antiseptic means. When the adhesions had been all detached, by tearing or by the knife, I reduced the viscera and then pared the edges of the orifice by which the sac communicated with the abdominal cavity, cutting off the peritoneum from the muscular and fibrous structures, and then stitched those edges securely with closely applied interrupted sutures of prepared catgut, the ends being cut off near the reef-knots. The external wound was then stitched and treated antiseptically like an ordinary one. During the introduction of the deep stitches the patient vomited violently, so that it was only by exerting very firm pressure that I prevented further visceral protrusion, and after going back to bed she vomited again—a tremendous test for our catgut stitches; but they stood the test. The young woman left the hospital without any hernia; and though a very small protrusion did afterwards appear below one part of the cicatrix, it was readily reducible and amenable to ordinary treatment by means of a truss."

ANTISEPTIC SURGERY. REMARKS MADE BEFORE THE SURGICAL SECTION OF THE INTERNATIONAL MEDICAL CONGRESS, PHILADELPHIA, 1876 (Transactions of the International Medical Congress, 1876)

The fifth session of the International Medical Congress was held at Philadelphia, in September, 1876. Lister was made president of the Surgical Section.

By invitation he delivered an address upon "Antiseptic Surgery." He spoke for two hours and a half, and occupied another hour in the discussion which followed.

In the address he attempted to meet "some of the objections which have been raised against this plan of wound treatment." But in greater part his "remarks" were occupied with the "enunciation of the germ theory, and in explanation of the process of decomposition in the secretions of a wound."

He exemplified his method of wound dressing, and exhibited his spray apparatus.

Lister's ideas met with strong opposition from the surgeons present, and were received with misgivings by the medical press.

During his address he touched upon the ligature as follows:

"Without strict antiseptic treatment, it is impossible to freely lay open a knee-joint, with the certainty that no danger will follow; or to take out a wedge-shaped piece from either femur, as I have recently done, and yet to feel that such a produced compound fracture is perfectly safe, and without risk. And then we must consider the progress of the wound. The blood becomes organized under the dressings, and cicatrization occurs without one drop of pus, and almost without granulations, so that, when we take away the superficial blood-crust, a clean surface is found beneath. This I venture to say never could be done without antiseptic treatment. Again, to be able to open a chronic abscess of the spine, without fear of irritative fever, or pyæmia, requires the strictly antiseptic plan. And in acute abscess, it is pleasant to feel that after the procedure of opening and pressing out the accumulated material, not one drop more will form. Again, in the ligature of a large artery near a great branch, it is a great relief to know that rapid healing will occur, and that the danger of hæmorrhage will be avoided. None of these things can be done without risk, unless putrefactive changes are strictly prevented.

"I have been making strenuous efforts to improve the cat-gut ligature, and believe that I have at last obtained the desired result. Old ligature is far preferable to new, and yet the knots will sometimes loosen. I have seen a case of Cæsarean section progress admirably until the stitches in the uterus gave way, and then death speedily followed. The old ligature is harder and does not absorb as readily as the new, but I have found that gut which is reliable when tested with warm water, will yet loosen under the action of the liquor sanguinis. The ligature must not be made too hard, or it will be too stiff for tying, and will even act as a foreign body as much as silk does, and yet it must be so hard that after soaking in serum for weeks it will still hold firmly. I have tried many substances; chromic acid will harden the gut, but when the latter is soaked in serum it is as unsatisfactory as before. Glycerine gives a ligature which will knot well, but is still too hard. I have at last made a mixture of carbolic acid, glycerine, chromic acid, spirit of wine,

and water, which I think will prove the very thing required. The ligature which I show has been soaked a month in serum, and yet the knots are perfectly firm."

RECENT IMPROVEMENTS IN THE DETAILS OF ANTISEPTIC SURGERY
(*Lancet*, 1875, Vol. I, pp. 365, 401, 434, 468, 603, 717, 787)

Many improvements and changes had been adopted by Lister in the four years elapsed since his Plymouth address before the British Medical Association (1871). These were detailed in a long article running through seven numbers of the *London Lancet*.

In the course of the paper he illustrated the use of the button suture—"stitches of relaxation." He recommended the use of silver wire for the deeper sutures in plastic operations, and horsehair for superficial sutures. He emphasized the fact that "the quality of the catgut improves the longer it is stored in the preparing fluid (carbolyzed oil)."

DEMONSTRATIONS OF ANTISEPTIC SURGERY BEFORE MEMBERS OF
THE BRITISH MEDICAL ASSOCIATION (*Edinburgh Medical Journal*, Vol. XXI, 1875-6, pp. 193, 481)

At a very early hour in the morning, upwards of five hundred members gathered to witness Lister's "demonstrations" or clinics. At these meetings actual cases were exhibited, operated upon and antiseptic dressings applied.

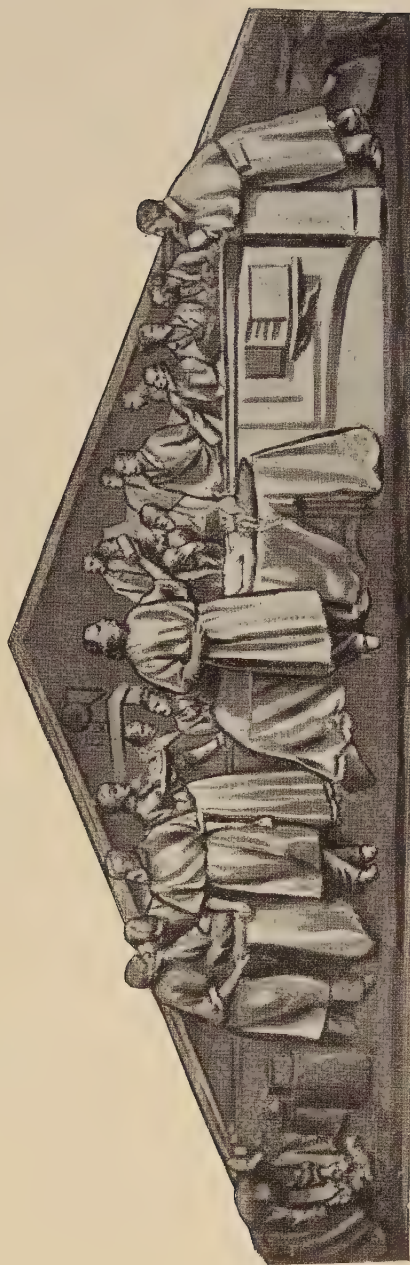
Some of the cases which involved a demonstration of ligatures and catgut were as follows:

DEMONSTRATION II—PART I

"Gentlemen—The first patient I wish to show you to-day presents an illustration of the effects of ligature of an artery in its continuity by means of prepared catgut applied antiseptically.

"The case was one of aneurysm of the upper part of the femoral artery. The external iliac artery was tied under spray. The wound was absolutely skin-whole in fifteen days, without the occurrence of any suppuration at all.

"The immediate object of the operation has therefore been attained—the vessel has been permanently obstructed at the part tied; and this has been done without the occurrence of



BAS-RELIEF TO LISTER, which occupies the tympanum of one of the two principal façades of the Policlinico Umberto I, Rome.

Lister is the central figure, standing in a marble theatre by the side of a table on which reclines a patient recently operated upon. He is expounding the case to the audience, while his staff of assistants and nurses occupy themselves with various duties in the background.

any suppuration, and by a mode which, I think we may venture to say, involves no danger whatever, provided it be properly carried out. The two great risks of an operation like this are, of course, secondary haemorrhage and diffuse suppuration in the cellular tissue around the peritoneum; and both of these are securely guarded against by proceeding in this manner. I believe myself that this is a pretty perfect method of obstructing a vessel in its continuity; I do not see that we can wish to have it improved upon. I therefore regret extremely to find that it is still distrusted in various quarters, even by those who use catgut for the ligature of arteries in ordinary wounds. They do not trust it for tying arterial trunks in their continuity. I regret this the more, because I feel it is to a certain extent my own fault. When I first published on the subject, I was not aware myself of the proper mode of preparing the catgut. I had prepared it right, but by a mere accident. I described the mode of preparation as steeping the catgut in a mixture of carbolic acid and oil. It so happened that the carbolic acid which I used was liquid carbolic acid, so called—that is to say, crystallized carbolic acid, liquefied by the addition of water. Now, this water makes all the difference in the world. When oil is added to this liquid carbolic acid, a considerable portion of the water is deposited in the form of very fine particles, which are suspended in the oil; and it is this mixture—this emulsion if we may so call it—of oil and water which causes the remarkable physical change in the animal tissue of which catgut is composed, that alone renders it fit for our objects.

“The tissue of the catgut in the ordinary condition is utterly unfit for surgical purposes; as slippery, when moistened, as a piece of intestine in the dead-house—when you tie it in a knot, it slips with the utmost ease. But after it has been steeping in the emulsion of carbolic acid, water, and oil for a certain length of time, it undergoes a physical change, which I am quite at a loss to explain. As the tissue lies steeping in this mixture, the first effect is to moisten it somewhat; then, as time passes, after about a week, you find that, instead of becoming softer, more swollen, and more opaque, as you would expect, it is, on the contrary, growing less opaque and beginning to shrink; and in about three months, though still softer than dry catgut, it is comparatively firm, and quite transparent. Now, if you take a fresh piece of dry catgut and put it into this same sample of the preparing liquid, you will find the second piece become

in the first instance partially moistened like the first; a fact which renders it inexplicable to me, why the former piece should have undergone what looks like a partial drying. But whatever the explanation, the all-important fact is this, that after the catgut has been thus partially dried, so to speak, in this moist liquid, it is now no longer liable to be made slippery by being steeped in water or the animal juices at the temperature of the body: it is indeed rendered softer and somewhat opalescent, but a reef-knot tied upon it holds better than one on waxed silk.

"I repeat, when I first published on the subject, I was not aware of this circumstance. I had got the catgut properly prepared, but it was by mere accident that the water which is essential to the process was present in the mixture that I used; and, ignorant of its importance, I omitted to mention it in the description which I gave of the mode of preparation; whereas mere steeping of catgut in a solution of dry carbolic acid in oil, though it of course makes it antiseptic, leaves it perfectly unfit for use as regards its physical properties. When I found out my mistake, I sought to remedy it by insisting, in subsequent publications, upon the importance of the presence of the water in the preparation of the catgut; but I never stated, as I now do, that I had originally described an untrustworthy method. I very much regret this bad result of what turns out to have been premature publication; and I earnestly hope that this public confession of my mistake will have the effect of preventing any further bad consequences from it.

"The catgut does not spoil by being kept a long time in the preparing fluid of oil, carbolic acid, and water. Here is some that was put in six years ago last month. It is now just as good as ever. Thin as it is, I cannot break it with any reasonable force. If you were going to tie the external iliac, you would use a thicker piece than this; partly, in order that it may stand any strain to which it could be reasonably subjected in the act of ligature, and partly that, a longer time being required for the absorption of the more substantial material, it may remain longer as a mechanical barrier to the force of the circulation.

"In this point of view there is another important advantage possessed by catgut properly prepared, viz., that it is much less rapidly absorbed than that which has been for a shorter time in the preparing liquid.

"I would strongly advise any surgeon, who proposes to ligature an artery in its continuity with catgut, to test for himself the

quality of the article; since those who sell it are tempted, if their stock of old catgut has run out, to supply that which has not been long enough prepared. In order to ascertain if it is trustworthy, a piece should be steeped for an hour in water about the temperature of the body, as in a vessel at a suitable distance from the fire. If then a reef-knot tied upon it does not slip, it is fit for use. And it will be well for the surgeon to keep a stock of the material for special purposes like these, testing it in the first instance in the manner described, after which he will be sure that, being still kept in the preparing liquid, it will be at least equally good at any subsequent period. If these points are attended to, there will be no further complaints about untrustworthiness of the catgut.¹

"I have now, Gentlemen, to bring before you two cases illustrating a somewhat interesting example of the usefulness of the catgut, namely, for the arrest of hæmorrhage from a wounded vein.

"Nineteen days ago I removed this patient's mamma, and at the same time cleared out the entire contents of the axilla, thus taking away, along with the fat, a number of scirrhus lymphatic glands, one of which lay immediately beneath the clavicle. In performing the operation, you may cut freely enough on the side towards the chest; but towards the axillary vessels, the glands,

¹ When it is requisite that the cord should be able to withstand all the strain to which the human hands can subject it, as, for example, if it be used for the pedicle in ovariectomy (in which case, I may remark, the pedicle would have to be well subdivided), the material must be of specially strong quality to begin with. Catgut consists of the peritoneum, together with muscular fibres, of the small intestine of the sheep; and the common kinds are either the entire tube of the gut, or longitudinal strips (according to the thickness required) simply twisted, dried, and subjected to sulphurous-acid vapour, or other chemical agents. But for special purposes, as, for example, the manufacture of fiddle-strings, the cord is made of several narrow strips twisted together, and is then very much stronger. Such catgut can be obtained of the musical-instrument makers, but is of course then unprepared in our sense, unfit for surgical purposes, and must be kept in the preparing liquid for a due length of time. For the sake of those who wish to prepare catgut for themselves, I may repeat here the proportions which I have found the best for the purpose. Add one measure of water to ten parts by weight of crystallized carbolic acid, mix and add one measure of the mixture to five measures of olive-oil, in a suitable jar or wide-mouthed bottle; then at once introduce the catgut, the hanks being opened up to allow access of the liquid to them; cover, and set aside in a cool place. Some water is gradually precipitated to the bottom of the vessel, and it is necessary to prevent any part of the gut from coming in contact with this precipitated water. A simple way of ensuring this is to put in as many marbles as will cover the bottom of the vessel.

with the loose tissue about them, should be detached with the fingers, and any considerable-sized venous branch tied before it is cut.

"In the present case, one of the glands was so very close to the vein that, as I was endeavouring with the fingers to detach it, a venous branch broke at its origin from the axillary, the result being an aperture in the venous trunk about an eighth of an inch in diameter. I seized the opening in the vein with catch-forceps, and put a catgut ligature upon it, but the thin slippery tissue of the venous coat slipped from the grasp of the knot. I made a second similar attempt, and again the same thing occurred. What was now to be done? Without antiseptic treatment I should have been a good deal at a loss. To have obstructed the main vein of the limb by tying it across like an artery, would have been most undesirable; and to have introduced a pad of lint into the wound, to compress the orifice, would have been very unsatisfactory practice.

"I did, however, what I had long contemplated doing, if such a circumstance should arise. All flow of blood being temporarily stopped by pressure on the vein to the distal side, I threaded a fine sewing-needle with the finest catgut, and passed it through the coats of the vessel at opposite points of the wound, and at a short distance from its edges, and then, cutting off the needle so as to leave two threads in its track, tied one thread round each half of the wound. The purchase thus secured upon the venous texture prevented the ligature from slipping, and the bleeding was permanently arrested. The healing of the wound has proceeded undisturbed, and cicatrization is, you observe, already almost complete.

"The other patient whom I wish you to see, as an illustration of the arrest of venous haemorrhage by means of catgut, will now be brought in. She had long suffered from varicose veins, which you see conspicuous in the leg, even in the recumbent position in which she is; and I was asked to see her on account of haemorrhage that had occurred from a tumour about as big as an orange, which had formed in the ham, the most prominent part being formed of blood-clot. It was evidently composed of a mass of greatly distended veins, one of which had given way by ulceration. The case seemed urgently to demand interference, and I resolved to remove the mass—a thing which I should have hesitated in doing without antiseptic measures, as I felt sure that I should open into large varicose veins.

Such proved to be the case, as you see from this preparation of the part removed. On section, the most prominent portion is shown to be composed of coagulum, while the deeper surface presents numerous large vessels. They have shrunk a good deal since they were removed, but when the operation was performed they were almost as thick as my little finger. And now we have to speak of how the veins, which lay open in the wound, were dealt with. Some of them presented transverse orifices, but others had been divided more or less longitudinally. I tried, by detaching the veins from the surrounding parts, and clipping away some portions, to get the vessels to present themselves in transverse section, so that I might tie them with catgut in the ordinary way; and in most instances this was satisfactorily accomplished. But there was one large vein presenting a longitudinal slit about five-eighths of an inch in length, so connected that I could not readily deal with it as with the others. I therefore adopted a practice which will, I believe, prove a valuable addition to our resources, in wounds of large venous trunks. Using a very fine sewing-needle and finest catgut as before, I sewed the two lips of the wound together by continuous or glover's stitch; leaving the calibre of the vessel intact. Now, I do not think any man would have been justified in doing that with ordinary silk or cotton without antiseptic measures. To do so would have been to run imminent risk of suppurative phlebitis and pyaemia. But by proceeding antiseptically we incurred, as I believed, no such danger, and the result is, as you see, so far satisfactory. It is now three days since the wound was dressed last, and five days after the operation. The discharge of the three days has caused, you observe, a merely trifling serous stain upon the gauze. And there is entire absence of any inflammatory disturbance."

CLINICAL LECTURE ON A CASE OF EXCISION OF THE KNEE-JOINT, AND HORSEHAIR AS A DRAIN FOR WOUNDS, WITH REMARKS ON THE TEACHING OF CLINICAL SURGERY. DELIVERED AT KING'S COLLEGE HOSPITAL, DECEMBER 10, 1877 (*Lancet*, 1878, Vol. I, p. 5)

Lister's lectures on first assuming the Professorship in King's College Hospital met with scant attention. There were many misunderstandings that only time could resolve.

In this published lecture he compared the use of horsehair with catgut for drainage, as follows:

"While the horsehair has the advantage over the catgut that it can be used when necessary over a longer period, it has, in some cases, the converse superiority that it can be not only reduced in bulk, but withdrawn altogether at an earlier period than is required for the absorption of the catgut; for the catgut, in process of organization and absorption, becomes more or less incorporated with surrounding tissues through the medium of the cells of new formation which invade it, and, if an attempt is made to withdraw the drain in whole or in part, there will often occur inconvenient oozing of blood through the rupture of newly formed vessels. And if, on the other hand, the drain is left intact till the parts of the catgut within the wound are entirely absorbed, there remains a small granulating sore at the place of exit of the drain, which may retard for some days the complete healing of the wound. Further, the threads of the catgut, as they undergo organization, are increased in bulk by the formation of the new cells, and their interstices are liable to be more or less choked, so as to interfere with effective drainage. The horsehairs, on the other hand, lie unchanged among the tissues, and their interstices remain to the last as effective as they were at the outset."

AN ADDRESS ON THE CATGUT LIGATURE, DELIVERED BEFORE THE
CLINICAL SOCIETY OF LONDON, JANUARY 28, 1881 (Clinical
Society's Transactions, Vol. XIV)

The inaugural address on his election to the Presidency of the Society, in which the results of his arduous labors in respect to catgut are unfolded.

According to Godlee, Lister's introduction of catgut completely changed the method of arresting haemorrhage in wounds, and made the tying of arteries perfectly safe instead of an "anxious proceeding." It did away in a stroke with the old plan of leaving long ends of thread hanging out of the wound.

"In considering the choice of a subject for the inaugural address which is expected from your President, I have decided to bring before you this evening a special subject, which will, I trust, be thought not unworthy of the occasion, inasmuch as, while it is still in an unsettled or transitional state, it is full of interest for every practical surgeon, and at the same time, in some of its aspects, well deserves the attention of the pathologist and the physician—I refer to the catgut ligature.

"The catgut ligature has in some respects exceeded my original hopes. I feared that its advantages would be limited to wounds in which putrefaction was avoided, and that, if septic suppuration took place in a wound in which it was employed for securing the vessels, the ligatures would, sooner or later, come away like little sloughs. Such, however, has not proved to be the case. Whatever be the progress of the wound, we never see anything of the catgut; so that even surgeons who have not adopted strict antiseptic treatment have been led to employ the new material in ordinary wounds. Under other circumstances, however, the catgut has often led to disappointment. We hear of cases in which the Caesarian section has been performed, and all has gone on well until the knots of the catgut with which the uterine wound was secured have given way, and the patient's death has been the result. Again, in ligature of large arterial trunks in their continuity, several surgeons have met with bitter disappointment, the case ending in disaster from secondary haemorrhage, or the treatment proving abortive through the channel of the vessel becoming opened up again at the site of the ligature.

"Hence many surgeons have been induced to return to silk, even though using strict antiseptic treatment—rendering

the silk aseptic by steeping it in a suitable lotion, and cutting the ends short. This practice has, however, by no means proved uniformly successful. As an instance of unsatisfactory result, I may mention a case which was recorded by Mr. Clutton in the last volume of our *Transactions*. He tied the external iliac artery with silk under strict antiseptic precautions, and the wound healed within a week; but, as I learned from a letter which he was good enough to send me at the time, 'six weeks after the operation a little blister formed, and fluid began to escape, forming a small scab, and in three months the loop which had been placed around the artery came away.' Such a result was not at all surprising to me, seeing that what induced me to try the animal ligature was the discovery of a small abscess about the remains of a partially absorbed silk thread which I had applied in the same manner as Mr. Clutton, and, as it so happened, to the same artery. It can hardly be doubted that suppuration proceeding from the immediate seat of the ligature must be a source of danger.

"As an illustration of the mischief which a ligature of ordinary material may do, I may mention a case of goitre in a young woman on whom I operated on the 28th of January last year. It was of moderate dimensions; but the effect on the respiration was so considerable that I determined to remove it, following Dr. Patrick Heron Watson's plan of preliminary deligation of the thyroid vessels circumferentially to the tumour. In order that the circumferential ligature of the thyroid vessels may be secure, it is essential that the material employed should be very strong, so that the tissues round about the tumour, including the vessels, may be thoroughly tightened up. I possessed no catgut which I felt was resistant enough to bear the full strength of my hands, and therefore I was compelled to use the hempen ligature—after, of course, carefully rendering it aseptic by means of carbolic lotion. Six of these hempen ligatures were used—three on each side. During the first eight days, everything went on in a typical fashion according to the antiseptic method. There was a merely serous effusion, rapidly diminishing in amount; and we looked to the wound being healed in a few days more. But on the ninth day there was seen to be a little something of purulence mingled with the discharge; and the pus afterwards became thicker, though always in small quantity; a little could be pressed out from each side; and in a month, one

of the hempen ligatures made its escape. Six days later, four others of the hempen threads came away altogether unaltered.

"I submitted them to careful examination. They had a sour odour, and, applied to litmus paper, gave an acid reaction, that is to say, the natural alkaline condition of the blood-serum had been changed to acidity by some peculiar species of fermentation. On examining them with the microscope, I found the interstices of the threads of the hemp loaded with a form of organism, to which I believe I happened to be the first to direct attention as to its mode of growth, and to which I gave the name of *Granuligera*, occurring in groups of two, three, four, and so forth, as distinguished from the chains of ordinary bacteria, and of which one species at least has been since shown by Mr. Cheyne to occur very frequently in cases treated antiseptically, without any interference with aseptic progress. I found that the interstices of the threads of the hemp were loaded with these little micrococci. It so happens that I have had the opportunity, within the last few days, of obtaining a sample of these micrococci, thanks to Mr. Cheyne's kindness. He brought this flask, containing then a pure and perfectly transparent organic infusion, to a case which I had operated on a fortnight before by excision of the ankle. The skin had been unbroken, so that I was able to operate antiseptically, and the case pursued a perfectly typical course. The wounds, which were left gaping at the time of the operation, were filled with blood-clot, which remained unaltered in appearance, though undoubtedly organized by that time, more or less. A little piece of the blood-clot from one of these wounds was introduced with careful antiseptic precautions into the flask of clear fluid, and you see it is now turbid.

"But though, under ordinary circumstances, these micrococci may be present, as Mr. Cheyne has abundantly shown, and as the excision of the ankle I have just referred to illustrates, without causing any evil, yet there may be circumstances in which they may prove mischievous; and the case of goitre which I have been relating appears to have been one of these. The micrococci, developing for a protracted period in the interstices of the hempen ligature, produced their special fermentation of the serum in its most aggravated form. The acid serum became a cause of irritation; and thus the ligatures, which otherwise, being unirritating in their own substance, might have become encapsuled, and in due time absorbed, became causes of

suppuration. One of the six ligatures still remained unaccounted for. In due time we sent the patient home with a small sinus remaining, a little pus always discharging from it; but it was not until the middle of September that the last ligature came away, altogether unaltered. Now, gentlemen, there is no doubt whatever that, if I had had catgut which I could have trusted for the operation, the catgut ligatures would have been disposed of within two or three weeks, and the healing, instead of requiring eight months, would probably have been completed in a fortnight. Here, then, we have an illustration of the great disadvantage which may arise, even under antiseptic treatment, from the use of the ordinary forms of ligature.

"Animal ligatures of another kind have been provided by Mr. Barwell, in order to remove these difficulties, namely, strips of the mingled yellow elastic and unstriped muscular tissues which constitute the arterial wall, obtained by cutting spirally the aorta of one of the larger animals. But, though fully admitting the efficiency of these ligatures in his hands, I am given to understand that their form and size render them by no means very convenient, and, independently of this, I cannot but feel that it is unsatisfactory, if it can be avoided, to have a special material for this particular object, and that it would be better, if possible, to have the catgut in a thoroughly reliable condition. Catgut, of which I have samples here, is to be had all over the world in abundance. It is beautifully strong and smooth; it is made of various sizes suitable for all surgical requirements, and is extremely cheap. Wholesale, it is sold at 12s. per gross, that is to say, one penny per hank. But, as it comes from the maker, it is entirely unfit for the purposes of the surgeon. However beautiful it is in the dry state, it becomes soft and pulpy soon after it has been placed in blood-serum. In one of these glasses is a piece of unprepared catgut which was placed in warm serum this morning, obtained from the blood of a cow, and within half an hour it was in the condition in which it is at the present time—swollen, soft, and pulpy. A knot tied upon it in its present state would hold as little or scarcely better than would one on a piece of the slippery intestine from which the catgut is derived. It is essential, in order to fit the catgut for the purpose of the surgeon, that it be altered in its physical constitution so as to be no longer liable to this softening effect by the serum of the blood. It is a remarkable

circumstance that the blood-serum softens catgut even more than water does.

"It might have been expected, *a priori*, that a solution of a colloidal substance like albumen would have been much less disposed than water to permeate and soften an animal tissue like catgut; but it is otherwise, and therefore we cannot test the trustworthiness of catgut by steeping it in warm water, as I formerly used to do. In order to be sure that a given specimen will answer the purpose in so far as the knot is concerned, that it shall not slip, it is needful that we should steep it in blood-serum, a somewhat troublesome process, as it involves sending to a slaughter-house for blood.

"The method of preparing catgut which I published long ago answers the purpose very well, even for the ligature of arteries in their continuity, provided certain conditions be complied with; such, at least, is my own experience. This, indeed, has not been very extensive, but it has been sufficient to deserve consideration. I have tied altogether nine large arteries in their continuity with prepared catgut. Of these, one was a case of ligature of the carotid, in a young woman, aged twenty-two, with a pulsating tumour below the angle of the jaw, in the situation of a carotid aneurysm and with all the symptoms of that disease. The application of the ligature reduced to a certain degree the pulsation and the dimensions, but the further cure which we hoped for did not take place. She left the hospital with a pulsating tumour; and I heard only yesterday from the medical man under whose care she is in Scotland, that this tumour, for which I tied the carotid artery in 1874, still exists as a pulsating swelling, if anything, rather on the increase. But though, as regards the cure of the disease, the ligature was unsatisfactory, nothing could be more beautiful in its effect as respects the healing of the wound without supuration, and the permanent obstruction of the vessel at the seat of ligature.

"A case of traumatic arterio-venous aneurysm of the temporal artery, in a young man lately under my care in King's College Hospital, may be mentioned in this category, partly because the greatly dilated condition which the naturally small artery had assumed brought it up towards the dimensions of a large trunk, and partly because the concurrent ligature of the largely dilated veins would, without antiseptic means, have been justly regarded as of considerable danger. The others were all cases of ligature

of the femoral. Six were popliteal aneurysms. In all these cases, except two, catgut prepared by the old method was employed, and in all these nine cases the result was satisfactory, and recovery perfect, except as regards the young woman who has still the pulsating tumour in her neck.

"As to the mode of applying the ligature, I have always used a single reef-knot with short-cut ends, tying it sufficiently tightly to cause the giving way of the internal and middle coats. This latter point is not, perhaps, essential, as I long ago surmised, and as Mr. Barwell's experience with his aortic bands appears to indicate. But if, as is the case with catgut, the form of the ligature admits of it, the injury done to the deeper tunics is, I believe, advantageous, by leading to a salutary corroborative process of repair.

"Why, it may naturally be asked, has my own experience been more satisfactory with the catgut ligature than that of many other surgeons? There are, I believe, two reasons for this. One is that I have never ventured to tie an artery of considerable size in its continuity without having taken pains to ascertain that the catgut was of thoroughly reliable material; and the other reason is that I have adopted strict antiseptic means of treatment, not only during the earlier stages of the case, but to the last. So long as any part of the wound remains unhealed, antiseptic treatment of the strictest kind ought, I believe, to be employed. Even though the sore may seem to be superficial, there may still exist a sinus leading down to the site of the ligature; and if ordinary treatment, as distinguished from antiseptic, be employed, down this sinus the septic process may advance and invade the ligature, and lead at last to disaster from haemorrhage. I know that this has actually taken place.

"But although the catgut prepared after the old method answers very well if it be in proper condition, there is this great objection to that method: that it requires a long time in order to produce the requisite quality. At least two months are needed to make the ligature at all trustworthy. It is better at the end of six months, and still better at the end of a year. I possess catgut prepared in this way twelve years old. I have brought here a sample of such catgut, which has been steeping in warm blood-serum since this morning, and it will be seen that it remains translucent, and is comparatively firm, instead of being opaque and soft, like the unprepared catgut in the same serum.

"Now, the length of time that the present method requires is a very serious objection. It places the surgeon who has not prepared the catgut for himself, and kept it for a long time, at the mercy of the person who supplies it; and the person who supplies it, not being aware of the enormous importance of the question of time, if he happens to run out of that which has been long prepared, will sell what has been only a short time in the preparing liquid, and is, in consequence, altogether untrustworthy. A case illustrating this point occurred last year in my practice at King's College Hospital. A patient was admitted who had met with a severe wound on the ulnar side of the forearm, at the anterior aspect. The ulnar artery had been divided. This had been secured by my house surgeon, who had also tied with catgut the corresponding ends of the various tendons that had been severed. But, when I saw the patient next day, I found that he could not feel with his little finger and the adjacent side of the ring finger, and, therefore, it was evident that his ulnar nerve also had been divided, and my house surgeon had not thought of attending to the ulnar nerve. I therefore cut the stitches in the skin, and proceeded to explore the deeper parts of the wound, in order to find the ends of the divided nerve, and tie them also together with catgut; and I found that all the catgut sutures with which the ends of the several tendons had been tied together were lying absolutely loose; the knots had slipped within the twenty-four hours; and yet this catgut had been supplied by one of our ordinary instrument-makers. He had sent us what had not been sufficiently long prepared. I took care to use proper catgut for the ulnar nerve; and the patient left the hospital with restored sensation in the fingers. The length of time that it requires is, therefore, an exceedingly serious objection to the present method of preparation; and one great object which I have had in view, in a series of experiments on this subject, has been to devise a means, if possible, of preparation within a short time.

"These experiments—it may seem almost ludicrous to say so—have occupied two years of my leisure in the past, some time ago; and, after being interrupted by an accidental circumstance, have been continued in a more desultory manner since; but at length I feel myself justified in bringing before you a new mode of preparation, by which the catgut may in a short period be brought into a perfectly reliable condition.

“But before I allude to these experiments, which I must endeavour to do in a short compass—I should weary you if I were to bring a large proportion of my facts before you, though I may say, out of the hundreds of experiments I have performed on the subject, I have never performed one which has not added something to my knowledge of it—before referring to these experiments, I wish to say a few words as to what catgut is. Catgut, as you are all doubtless aware, is prepared from the small intestine of the sheep. The gut is treated in what seems an exceedingly rude manner for so delicate a structure. It is scraped with some blunt instrument, such as the back of a knife, over a board; and by this means, as the people express it, the dirt is scraped out. That which these persons call the dirt is the exquisite and complicated structure of the intestinal mucous membrane. But while the mucous membrane is scraped out from within, there is also scraped off from without, the circular coat of muscular fibres. The result comes to be that the intestine is converted into a comparatively unsubstantial material, consisting of two parts, or bands, one more slender than the other. When the intestine is stripped from the mesentery by the butcher, the peritoneal covering of the gut shrinks into a narrow strip, and this, with some longitudinal fibres, constitutes the more slender of the two parts to which the intestine is reduced by the process of scraping. The other part is the essential material from which the catgut is prepared, and this is neither more nor less than the submucous cellular coat of the intestine.

“When I first visited a catgut manufactory I was astonished to find that, after this scraping process, the intestine could be blown up still as a continuous tube, as you see can be done with this specimen, which has been treated in the manner I have described. This translucent membranous tube is a beautiful anatomical preparation of the submucous cellular tissue, though made in so rude a fashion. This coat of the intestine, which in the sheep has such extraordinary toughness, is the material out of which the catgut is prepared. For what the manufacturer terms the ‘ones’—the thicker form of ordinary catgut—all that is done is to twist the entire tube by means of a wheel, like a rope in a rope-walk, up to a considerable degree of tightness, and then allow it to dry. It is afterwards exposed to the fumes of burning sulphur, and for some more special purposes it is bleached by the action of potash. But the essential thing is the twisting and dry-

ing. It can be manufactured without sulphur, as well as without potash. Some specimens which I have here were made by means of water only, without the use of any other ingredient. This exceedingly beautiful material, as fine and smooth as a horsehair, is nothing but the animal tissue twisted and dried. For the finer kinds the submucous coat is split up by means of razor blades, more or less numerous, according to the degree of splitting required, connected with a conical piece of wood which is pushed along the tube.

"Such, then, is the material with which we have to deal. The first of the more recent experiments which I performed with reference to it was made with the view of ascertaining, if possible, what part the water played in the ingredients used for the preparation by our old method. If I steep unprepared catgut in a mixture of dry carbolic acid and oil, however long it be so steeped, although it will be of course abundantly aseptic, it remains utterly unfit for the purposes of the surgeon; a knot upon it would still slip in a wound. But if, instead of using carbolic acid in the crystalline state, we use carbolic acid which has been liquefied by the addition of a little water, we get in course of time a properly prepared catgut. I wished to ascertain how much water was required. The carbolic acid would enable oil to dissolve a certain amount of water; would that amount of water be sufficient which carbolic acid enables oil to dissolve? Accordingly, I prepared jars of carbolic oil, some containing the full amount of water we had used hitherto, some a smaller quantity, and some none at all, and placed in them portions of the same hank of catgut.

"In due time I proceeded to examine the result, by taking portions of gut and putting them into warm water and leaving them for a while, in order to ascertain how the knots would hold. To my great surprise, I found that which had been steeping in the carbolic acid and oil without any water just as good as that which was in the carbolic acid and oil with the water. This was contrary to distinct previous experience. Reflecting on the matter, I saw that the only possible explanation was that the catgut was already, so to speak, prepared before I put it in the liquid. Now it so happened that the catgut I had used was several years old; and it turned out that mere age of the catgut prepares it; that in proportion to its age it is rendered less liable to be softened by water or by blood-serum and a knot tied upon it will hold better. And thus I had for the first

time, I believe, scientific evidence of the truth of what is popularly spoken of as the 'seasoning' of various articles made of animal products. I asked a person who sold violin strings if there was any result from keeping the strings a long time. He replied that the only result he knew of was that they would probably get rotten. But it so happened just about that time there came an old fiddler to amuse the patients in the Royal Infirmary, Edinburgh, at Christmas time. The weather was wet, and he said that his fiddle would not work properly because the fiddle-strings were not properly seasoned. So he was aware that fiddle-strings, which of course are catgut, are liable to seasoning, and require it. The knowledge of this effect of the mere lapse of time was very important, because it enabled me to explain the success that I had had in my earlier experience with catgut before I knew at all the proper mode of preparing it. I look back with horror at some of my early procedures with catgut. I have operated, for example, on an irreducible ventral hernia, opened the sac, divided the adhesion, returned the protruding intestines, stitched up the mouth of the sac with catgut, and then applied stitches at considerable intervals in the skin. All went perfectly well; but the mode of preparation that I then used, if I had worked with catgut recently made, must have led, in such a case, to utter disaster; the knots must have slipped in a few hours, and the intestines must have been protruded through the wound.

"I need hardly say this mode of preparation, interesting though it is, would not be satisfactory; it would only have, in a more aggravated form, the inconvenience of the extremely long period which our old method demands. Besides that, it by no means fulfils all the conditions that are required for a perfectly satisfactory state of the catgut for surgical purposes. These conditions I will now mention. In the first place, I have spoken of a short period of preparation. This is very desirable. Then it is essential that the catgut should have proper strength, so as to bear any reasonable strain that the human hands can put upon it, in the thicker forms, as when used, for instance, in such cases as the circumferential ligature of the thyroid vessels in the removal of a goitre, or for securing the pedicle in ovariectomy. And it is not sufficient that it should be strong to start with; it is easy to get catgut strong in the dry state; it is necessary that it should be strong after steeping in blood-serum for a while.



MARBLE MEDALLION IN NORTH TRANSEPT,
WESTMINSTER ABBEY, LONDON
Design of Sir Thomas Brock

“Take, for example, the case of tumour of the thyroid. I employed six ligatures, and in a former case, where the tumour was larger, I thought it prudent to pass as many as eight, so as to subdivide more the mass that had to be tied; but it is not convenient to tie each of these ligatures as soon as it is passed, and the process of passing takes a considerable time. Now it would be a very sad thing if the residence of the catgut among the tissues soaked with serum for a few minutes, or even a quarter of an hour, should render it so soft that it should give way when we put the strain of the hands upon it. That, then, is another essential point, if the material is to be useful for all the purposes for which it is desired. Then, again, it is necessary that a knot tied upon it should hold with absolute security, not merely in the first instance, but after soaking for an unlimited time in blood-serum. It is further needful that it should not be too rigid; for, as we shall see immediately, it is possible for catgut to be over-prepared; in which case it may remain almost like a piece of wire among the tissues, and ultimately, perhaps, come away by suppuration in consequence of the mechanical irritation which it produces. But while the animal juices must be able to soften it sufficiently to render it mechanically un-irritating, yet, on the other hand, it will not do for it to be too rapidly disposed of by absorption. If it is to do duty for the ligature of an artery in its continuity in the immediate vicinity of some large branch, it must remain for a considerable time of good strength, unabsorbed; and, when it is at length absorbed, it is desirable that it should be removed in such a manner that, while it is reduced in thickness, it shall still, as long as any of it remains, retain its tenacity.

“Now, these are a series of conditions which, I assure you, it is not easy to fulfil completely. I have in various experiments complied with some of them easily enough, but failed in others. Sometimes I have succeeded with all but one, and one has baffled me. I have tried various materials, as you will naturally suppose. One substance that suggested itself was tannic acid, so as to convert the fibrous tissue of the catgut into leather. I succeeded well enough in some respects with tannic acid applied in different ways, but in one respect I did not succeed. I have not obtained by means of tannic acid a kind of catgut that is not too speedily absorbed. Even a piece of kid-leather, cut into a suitable shape for sutures, and rendered aseptic, became too rapidly absorbed.

"Chromic acid was another agent which I very naturally tried on account of its well-known effect in hardening tissues. Chromic acid alone does not work very well; but I found that the addition of some other substances to it aided its action very greatly. By adding, for instance, to the watery solution a little glycerine, thus producing a reducing action on the chromic acid, we get a different sort of liquid, which acts much more energetically on the catgut. I was highly delighted with the results of the action of this mixture of chromic acid and glycerine; and just at this time (June, 1876) it happened that Mr. Oliver Pemberton, of Birmingham, applied to me for a piece of catgut, for the purpose of ligaturing the external iliac artery in a remarkable case of three aneurysms in one limb—two in the femoral artery, and one in the popliteal. I thought I could not do better than send him a piece of my recently prepared chromic catgut. I did so; and a month afterwards he wrote to me, saying that nothing could be more satisfactory than the result. He had operated antiseptically; the wound had united by first intention; and, so far as the case could go well, all had gone well. There was, indeed, gangrene of the lower part of the leg, which Mr. Pemberton had predicted would occur in consequence of the existence of four successive obstructions in the course of the arterial channel; viz., the ligature and three solid aneurysms. But the case, under proper management, was doing well. Four weeks later, however, Mr. Pemberton wrote to me again, telling me that, soon after his last report, the patient had begun to show signs of suppuration about the seat of the wound. After a while the abscess opened in the cicatrix, and one day the ligature which he had placed on the artery was found lying unaltered on the granulations. It is now on one of the cards before you—an over-prepared ligature, which had come away, rigid and wire-like, making its way out, as a piece of glass might have done, by mechanical irritation.

"This opened my eyes for the first time to the possibility of having catgut over-prepared. This over-preparation by means of chromic acid is, I understand, to be found illustrated in a large German school at the present time. I have been told by an American physician, who has lately been in London after spending some time at that school, that the catgut ligatures come away from all wounds to which they are applied in that clinique. They count the ligatures as they put them on, and

invariably see them all before the case is done with. The catgut has been over-prepared.

"It is by means of chromic acid, however, that I have at length arrived at a result which appears to satisfy all our conditions. But, before speaking of the new method, I wish to say a few words more with regard to the old. To what is it that it owes its virtue? In this bottle is some catgut which has been nearly ten months in our old preparing liquid—namely, one part of carbolic acid which has been liquefied by means of water, to five parts of olive oil. In this other vessel again we have catgut which has been the same length of time in a solution of carbolic acid in water. Water will only take up about one-twentieth part of its weight of carbolic acid; but the effect produced upon the catgut by the watery solution is very much greater than that brought about by the four times stronger oily solution. In the former case, as you can see, the catgut is almost black, a sort of purple black; while the other is comparatively pale, very little altered from its original colour.

"This circumstance shows two things. In the first place the effect of the watery solution of carbolic acid upon the catgut explains the efficacy of the water in our old method. It is the watery solution of carbolic acid in the liquid of the old method that is the effective agent. But in the second place we see that, when the watery solution is mixed with oil, the fact that it is so mixed limits and checks its operation. If catgut is kept in the watery solution only, there seems to be no limit to the degree of continuous preparation of the gut—so that it becomes more and more dark in colour, and more and more difficult of absorption by the tissues. It is otherwise when the watery solution is blended with the oil. Though the process does go on for many months, there is a time when it comes to a standstill. You need not fear that catgut prepared by the old plan is ever over-prepared. There is a specimen on the table, which, at the end of twelve years, is as limp, after steeping for a while in blood-serum, as it would have been at the end of a single year. Therefore, we possess in the carbolic oil a means of checking any mode of preparation that we may adopt, keeping it from that time forward not materially further prepared; while at the same time the large proportion of the carbolic acid to the oil (1 to 5) ensures the catgut being maintained perfectly aseptic.

"The method of preparation which I have now the honour to bring before you is the following. I dissolve one part of chromic acid in 4,000 parts of distilled water, and add to the solution 200 parts of pure carbolic acid, or absolute phenol. In other words, I use a 1 to 20 watery solution of carbolic acid; only that the carbolic acid is dissolved, not in pure water, but in an exceedingly dilute solution of chromic acid. But minute as is the quantity of the chromic acid, it exerts, when in conjunction with carbolic acid, a most powerful influence upon the gut. The first effect of the addition of the carbolic acid to the chromic solution is to change its pale yellow colour to a rich golden tint. But if the liquid is allowed to stand without the introduction of the catgut, it changes in the course of a few hours to a dingy reddish-brown in consequence of some mutual reaction of the two acids, and a certain amount of grey precipitate is formed. If, however, catgut about equal in weight to the carbolic acid is added as soon as the ingredients are mixed, the liquid retains its brightness, and the only change observed is a gradual diminution of the depth of the yellow colour; the precipitate, if it still occurs, taking place into the substance of the catgut.

"As soon, therefore, as the preparing liquid has been made, catgut equal in weight to the phenol is introduced into it. If you have too large a proportion of catgut, it will not be sufficiently prepared; if you have too small a quantity, it may run the risk of being over-prepared.¹ At the end of forty-eight hours the chromic element of the liquid has nearly spent itself, and the process of preparation is complete. The catgut is then taken out of the solution and dried, and, when dry, placed in 1 to 5 carbolic oil; it is then fit for use. I have here a sample of catgut prepared by this method. Although it has been steeped in warm blood-serum since this morning at eleven o'clock, it is still translucent and firm without being rigid, and a reef-knot tied upon it holds with the most perfect security.

"The strength of the catgut depends upon different circumstances. In the first place, sheep differ as to the strength of their intestines; and the catgut-maker, if he understands his business, will insist upon having his raw material of a proper kind. In the next place, the intestines must not be allowed to putrefy—they must be used when quite fresh. For these things

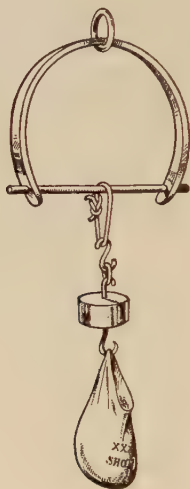
¹ A moderate excess of the liquid, not exceeding twice the prescribed amount, does not produce any serious degree of over-preparation.

you must, of course, rely upon the maker of the catgut. In the next place, the preparing liquid causes a certain amount of softening of the catgut, and if it is introduced in loose hanks, this will tend to produce a little uncoiling of the twisted cord, and a still greater degree of uncoiling will take place during drying. It is of very great importance that this should not occur, because it involves weakening of the thread, and that in different degrees in different parts; and this may lead to the gut giving way when you subject it to a strain. The catgut, then, should be prepared on the stretch both when it is put to soak and when it is put to dry.

"I need not enter into the mode in which this can be done by the manufacturer. I may only say this, that the surgeon who wishes to prepare it himself may do it in different ways. For instance, he may take two large test-tubes, one a little larger than the other, and he may wind the catgut on the smaller tube, fixing one end by sealing-wax, winding it round, then bringing it up again, and fixing the other end also with sealing wax at a higher level than the liquid will reach, putting sufficient liquid into the larger test-tube, and introducing the smaller test-tube with the catgut wound round it, and containing a little shot or other heavy material to keep it down in the liquid. After forty-eight hours he takes out the smaller test-tube, and leaves it till the catgut is completely dry. I merely mention this as an illustration, and also as furnishing a hint to some surgeons in private practice who may desire to prepare the catgut themselves. Or a couple of gallipots, one larger than the other, will do just as well. But, as I have already said, the principal uncoiling takes place during drying; and for all ordinary purposes a sufficiently good article is got by putting the catgut loose into the liquid, and making it dry on the stretch, by tying the ends of each hank to two fixed points in a room.

"In the dry state, catgut prepared by this method is as strong as need be. As to strength in the condition after steeping in blood-serum, I confess it is only this very day that I have obtained evidence that catgut thus prepared is really all that we can desire in that respect. The catgut of the hank from which this specimen was taken measured in the dry state $2\frac{2}{3}$ -hundredths of an inch in diameter, and broke at 13 lb. 6 oz. I have found by experiment that 10 lb. is the utmost strain that my arms are able to put upon a cord. Thirteen pounds six

ounces, then, is amply sufficient; while, at the same time, the catgut is not at all too large for going into the eye of an aneurysm-needle. Having obtained, the other day, some fresh blood of a cow from the slaughter-house, I took some of the serum to-day, and put two pieces of this same hank of catgut in the serum, and placed it in a stoppered bottle in a warm box at a temperature of 98° Fahr. After more than half an hour I tested the breaking strain. The mode of proceeding was as follows:



Apparatus for testing tensile strength of catgut, as explained in the text.

"A piece of steel, of horseshoe form, is suspended by a ring on the middle of its convexity, so that the horns of the horseshoe are dependent; these horns being perforated for the reception of a cylindrical bolt of steel, which thus lies horizontally, and can be removed at pleasure. A piece of the catgut having been tied in a double reef-knot, the bolt is partially withdrawn, and is readjusted after the noose of the catgut has been slipped over it. Into the lower part of the catgut-ring thus suspended is passed the upper end of a pot-hook, to the lower part of which are attached weights approaching what the gut is likely to bear, and also an empty bag, into which shot is poured till the cord gives way. The shot is weighed; and the result, added to the other weights, gives double the breaking

strain of the gut; for, as the cylindrical bolt works with perfect smoothness in its bed, it adjusts itself so as to prevent inequality of strain in the two sides of the catgut-ring, which thus take an exactly equal share in sustaining the weight.

"I found that the breaking strain of the same catgut which in the dry state had broken at 13 lb. 6 oz. was 11 lb. 4 oz.; that is, though supplied by the serum, it had only lost in strength two pounds out of thirteen. I think that is really all that can be desired.

"[A few days after the delivery of this address I made some experiments regarding the strength of the new gut after longer periods of immersion, using the serum which I had before employed for the purpose, and which, being derived from blood taken from a cow with antiseptic precautions, remained still perfectly sweet. I first tried the specimen of gut twelve years old, prepared by the old method, a portion of which I exhibited at the meeting steeped in serum. It is comparatively slender gut, having little more than half the thickness of the chromic gut with which I before experimented, the average diameter being $1\frac{2}{3}$ -hundredths of an inch. Two trials of it in the dry state gave 5 lb. 9 oz. as the average breaking strain; and two other pieces, after steeping half an hour in the warm serum, broke at 3 lb. 14 oz. In other words, this especially well-seasoned sample of what the old method could provide was deprived by warm serum of about one-third of its strength in half an hour. I next tested a piece of gut prepared three months ago by the new method, similar in thickness to the other, viz., having an average diameter of $1\frac{2}{3}$ -hundredths of an inch. Four trials with it in the dry state gave an average breaking strain of 6 lb. 15 oz. I then placed in the warm serum three other pieces of the same hank, after measuring their diameters. One of these pieces, with diameter $1\frac{2}{3}$ -hundredths of an inch, tested after it had been one hour in the serum, broke at a strain of 5 lb. 13 oz. Another piece, which when dry measured decidedly less in diameter than the first, was tried after being fourteen hours and a half in the serum, when it also broke at 5 lb. 13 oz. A third piece, just $1\frac{2}{3}$ -hundredths of an inch in diameter when dry, was left in the warm serum for twenty-four hours, at the end of which time it showed a breaking strain of 5 lb. 10 $\frac{1}{2}$ oz. Thus the new gut continued as strong, or nearly so, at the end of a day in the serum as it had been after the lapse of an hour, and lost in the serum only about one-seventh of

its full strength in the dry state, a result corresponding very closely with that obtained in the former experiment with the thicker chromic gut after forty minutes' immersion. At the same time, the new gut being considerably stronger to start with than that prepared by the old method, its strength, after steeping for twenty-four hours in warm serum, was greater than that of the old kind in the dry state.]

"The only remaining condition to be considered regarding the new catgut is its suitable behaviour among the tissues. Before describing this, I must say a few words regarding the manner in which catgut is absorbed. It has been said of late by various persons that the catgut is dissolved by the serum. I must confess that this is entirely contrary to my own experience. I have already said that, in order to test the quality of catgut, you must have it steeped in blood-serum. I have tested in this manner catgut prepared in various ways. The serum has sometimes been putrid, sometimes it had no smell at all, and sometimes it had a little odour. The serum has been kept about the temperature of the body, but I have never seen the slightest indication of any chemical solution of the catgut.

"Then, again, as to the behaviour of the catgut in the body: suppose we use it as a stitch, if the catgut were disposed of as a matter of chemical solution, we should expect that, when it is employed as a suture and a piece of our protective is put over it, which is always kept moist with serum perpetually oozing from the wound, the outer parts of the stitch, the parts outside the skin, as well as the parts among the tissues, would show signs of diminution. It is never so. The diminution is always absolutely limited to the parts within the tissues. It is still more striking, as was suggested to me by Mr. Cheyne, to consider the case of catgut used as a drain. There its very function is to drain out the serum, and it is perpetually washed with it. You might suppose that a stitch might perhaps become a little dry; but here there can be no mistake; the serum from the wound is perpetually flowing over the gut, yet, as in the case of the suture, we find the diminution of the catgut is absolutely limited to the part within the tissues. This seems to me sufficient evidence that it is not a question of mere chemical solution of the catgut, but of disposal of the catgut in some way or other by the living textures.

"Now, if we examine catgut in the process of diminution in the living body, we find that it may be affected in one of two ways. If it has not been properly prepared, the substance of

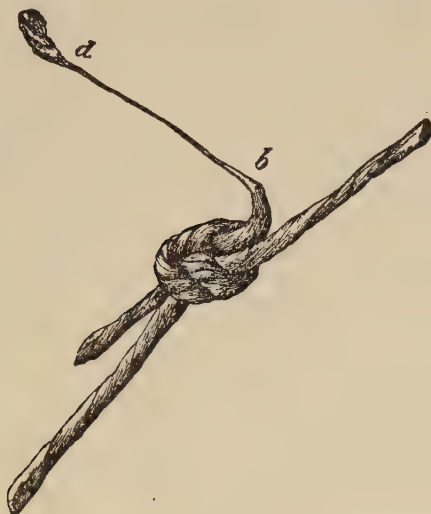


FIG. 1.—In this woodcut, the suture referred to is represented magnified. Its actual thickness was one-fiftieth of an inch. The part between *a* and *b* is that which had been among the tissues.

the catgut becomes converted, in the course of a very few days, into a soft pultaceous mass, which, when we examine it by a microscope, we see consists of remains of the old cellular tissue of the submucous coat, with the interstices among the fibres filled with cells of new formation. The catgut tissue is infiltrated with young growing cells, and it is obvious it is this infiltration which is the cause of the softening. But, on the other hand, if the catgut is properly prepared, instead of being infiltrated by the cells of new formation, it is only superficially eroded. In this stitch (Fig. 1) of catgut prepared by the new method, removed from a wound thirteen days after its introduction, you have a good example of this important fact. You will see that, at the part which was among the tissues, there remains a very slender residue of the catgut, all the rest having gone; but that slender residue was pretty tough, and remained translucent, showing not even a

superficial infiltration; in short, having exactly the characters that we desire for catgut for the ligature of an artery in its continuity, namely, that it shall not disappear too rapidly, and that till the last, even though reduced in dimensions, it shall retain some degree of its original firmness and tenacity.

"We know that antiseptic treatment has shown that a piece of dead bone may be absorbed, provided it be not putrid; the granulations that overlap it superficially may, so to speak, erode it. It is not necessary for us now to consider how that is effected; but certainly, in some way or other, the granulations do what mere steeping in serum, whether putrid or non-putrid, never would do. Never, I believe, would the bone be dissolved by the serum; and just as a non-putrid sequestrum is served by the tissues, so is a well-prepared specimen of catgut; it is superficially eroded. I have here a stitch that I removed to-day from a wound made ten days ago—a wound made for stretching the anterior crural nerve, which, as well as the sciatic, was subjected to that treatment, in an aggravated case of sciatica. You may see that, as yet, it shows no signs of erosion. We know by experience that, if it were left three or four more days, we should probably find it eroded, as the former specimen indicates; but until nearly a fortnight has elapsed erosion does not begin. It then proceeds gradually, and, therefore, the thicker the catgut the longer is the time required for its complete removal. We may fairly consider that from a fortnight to three weeks is long enough for the persistence of a ligature upon an artery in its continuity. [Three days later I removed two remaining stitches in the case last referred to, and found both of them slightly eroded superficially.]

"I have brought with me this evening a preparation of the carotid artery of the calf in which I first established the fact of the substitution of new living tissue for the dead old tissue of the catgut. If any gentleman will examine the specimen after the meeting, he will see the ligatures of new formation incorporated with the external cellular coat of the artery. I have been strangely misunderstood as having intended to convey the idea that the catgut, when it becomes organized, comes to life again. Gentlemen, such an absurd notion certainly never entered into my head; any more than, when I have spoken of the organization of a blood-clot, I have meant by that expression to convey the idea that the blood-clot becomes organized by its own inherent virtue. I found the term 'organization'

ready to my hand; it was not a word of my invention. It had been used with reference to lymph. Now, pathologists, in speaking of lymph as becoming organized, did not, I suspect, mean by that expression to imply that it was the lymph-substance that had the power of self-organization, as distinguished from any influence that surrounding tissues might exert upon it. So in the same way the expression 'vascularization of lymph' was used when it was universally believed by pathologists that the new blood-vessels were formed only as loops from pre-existing blood-vessels. Nowadays a different view may be taken, but the term 'vascularization of lymph' was employed without any notion that the lymph itself created the blood-vessels.

"And so when I spoke of the organization of the blood-clot or of catgut I never meant to convey the idea that the one or the other did the work itself. As to the blood-clot, we know that if it remains free from putrefaction among the tissues, it speedily becomes infiltrated with cells of new formation. Whether the white corpuscles originally present in the clot take any part in the formation of these new cells is a question now under discussion, and one, I conceive, not at all prejudiced by the use of the term 'organization of the blood-clot.' With regard to catgut, I think, if gentlemen would refer to my original paper in the *Lancet*, they would see that I stated very explicitly that new tissue forms at the expense of the old, that the old tissue is absorbed by the new, and that as the old is absorbed, new is put down in its place.

"In conclusion, gentlemen, I venture to recommend the new chromic catgut as in all respects deserving of your confidence."

ON AMPUTATION (Holmes's "System of Surgery," Vol. III, third edition. London, 1883)

Holmes's System of Surgery was a compendious encyclopedia of four volumes containing contributions by men of the highest standing in the profession. Lister himself states that the authors were "all London surgeons of more or less standing in the profession, except myself."

The book passed through three editions. Lister's article was originally written in 1861, and was revised for the 1883 edition. In the 1861 article he recommended the dry dressings and drainage. In the 1883 edition he says "only a stump after

amputation is dressed on the same general principles as other wounds."

His method of bloodless operation is noted.

In an historical discussion of the ligature, Lister says:

"Celsus employed the ligature for arresting hæmorrhage after amputation, and dressed the stump in a manner favourable to the occurrence of primary union.

"During the Middle Ages, the ligature, though used for ordinary wounds, was never thought of in amputation, and whatever may have been the practice of Celsus in this respect, there is no doubt that the great French surgeon Ambroise Paré, when he so applied it, in the middle of the sixteenth century, had all the merit of originality. But, though he urged its superiority over the cautery with able argument, supported by his extensive experience in both military and civil practice, yet his teaching failed for a long time to influence surgeons generally, either in his own country or in other parts of Europe.

"The principal reason for this appears to have been that the fillet, which was the means still in use for controlling the bleeding during the operation, did not answer its purpose effectually even in the ablest hands: so that the dread of hæmorrhage led most surgeons to prefer the cautery as a more expeditious method than the ligature.

"The tenaculum, long universally employed for seizing the bleeding vessels in order to tie them, has been superseded by the catch-forceps, which, like the bone-pliers, were introduced into surgical practice by the late Mr. Liston. Besides being always more convenient, they have the great advantage of making the surgeon independent of an assistant in cases of emergency. The ligature should be tightly and securely tied, by reversing in the second half of the knot the relation that the ends of the thread had to one another in the former half, or, in the language of sailors, by making a 'reef-knot.' The larger arteries should be drawn a little way out of their sheaths, as the best means of avoiding nervous trunks and other unnecessary tissue. The principal veins also should be tied; the dread of exciting phlebitis by such treatment having proved entirely groundless. As regards smaller vessels, the old rule was to tie only such as furnished a distinct pulsating stream. But as the catgut ligature with short-cut ends has none of the inconveniences of the long threads of silk or flax formerly employed, there is now no objection to tying mere oozing-points, however

numerous; and this practice has the great advantage that it banishes all risk of reactionary hæmorrhage.

"The catgut, of course properly prepared to fit it for surgical purposes, should be used of as slender quality as will bear the strain of tying; except in the case of advanced atheroma, when the finer kinds may be found to cut through the degenerated tissues of an arterial trunk, and a thicker sort must then be employed for the principal vessels. If the ligature cannot be made to hold when applied round the point of the forceps in the usual way, as when fibrous tissue is condensed by inflammatory infiltration, the difficulty may always be overcome by threading a fine curved needle with catgut with both ends long, and passing it so as to take a substantial hold of the tissues at the site of the bleeding-point, cutting off the needle, and tying the two pieces of gut one at each side. The bleeding vessel will be sure to be included in one of them."

AN ADDRESS ON THE PRESENT POSITION OF ANTISEPTIC SURGERY,
DELIVERED BEFORE THE INTERNATIONAL MEDICAL CONGRESS,
BERLIN, 1890 (*British Medical Journal*, 1890, Vol. II, p. 377)

Before an assemblage of five thousand people, characterized by Paget as "a strange mixture of science, utter heat and confusion," Lister delivered this address, memorable for the definite abandonment of the famous spray.

He mentioned the use of cotton sterilized by heat.

In acknowledging the truth of the phagocytic theory of Metchnikoff, he said:

"By means of this same theory we can account for what would otherwise have seemed to me incomprehensible—the use, without evil consequences, of silk ligatures which have not been subjected to any antiseptic preparation. We learn from the experiments of Ziegler and others that leucocytes soon penetrate very thin spaces between plates of glass or other chemically inert foreign bodies inserted among the tissues. And we can understand that they may creep into the intervals between the fibres of a silk thread and destroy any microbes that may have lodged there before they have had time to develop serious septic mischief. But there must surely be a limit to the thickness of the threads. No one, I imagine, would feel justified in leaving in the peritoneal cavity an unsterilized cord as thick as a finger. Dr. Bantock, whose remarkable series of successful

ovariotomies may seem to justify his practice, does not, I believe, prepare his ligatures antiseptically; and I understand that he uses, for tying the pedicle of a tumour, silk twist of so strong a nature that it can be trusted to bear the needful strain, with a diameter of only about 1/30th of an inch. But it would surely be wiser to sterilize even so slender a cord. Who can say that septic mischief may not occasionally lurk in the ligature in a form which may baffle the phagocytes?"

ON THE PRINCIPLES OF ANTISEPTIC SURGERY (Virchow-Festschrift, Bd. iii, 1891)

It was considered a high honor to be called to contribute to that peculiarly German classic, the Festschrift, especially when given for so distinguished a savant as Virchow.

In speaking of catgut, he notes that the presence of the anthrax spore-bearing bacillus had been observed in catgut "prepared from the intestines of sheep that had no doubt died of that disease. But the care now taken in the preparation of catgut would prevent the infection being carried to the wound."

He states that "with the exercise of scrupulous care on the part of all concerned, the troublesome complication of irrigating during the stitching may be omitted."

AN ADDRESS ON THE ANTISEPTIC MANAGEMENT OF WOUNDS (*British Medical Journal*, 1893, Vol. I, pp. 161, 277, 337, with subsequent corrections)

This lecture was delivered at King's College Hospital, in the London Post-Graduate course in January, 1893, after his retirement by age limit from the professorship.

He reiterates the foundation principles of antisepsis—"first, during the operation to avoid the introduction into the wound of material capable of introducing septic changes in it; secondly, to dress the wound in such a manner as to prevent the subsequent entrance of septic mischief.

"Advancing knowledge has enabled us to greatly simplify our procedure. The living animal body has the power of defending itself against microbes introduced into it, chiefly, as it appears, by the process of phagocytosis, which Metchnikoff has revealed.

"We are able to disregard in our operations the once dreaded atmospheric dust. Hence, we may dispense entirely with irrigation, whether in the form of spray, which was a kind of irrigation, or any other method.

"It is a happy thing for us as surgeons that those organisms which have the most resisting spores do not trouble us in surgical work. For instance, the hay bacillus, which is sure to grow in an infusion of hay left exposed for a while, has spores of an exceedingly resisting kind; but supposing the hay bacillus to get into a wound it would do no harm whatever. Again, the anthrax bacillus has very resisting spores, but if we take good care that the catgut which we use for tying bleeding vessels has been treated with an antiseptic that will certainly kill any spores of anthrax with which the sheep might have been affected that furnished the intestines for the catgut, we shall never have any chance of anthrax getting into our wounds. What we have to deal with as our surgical enemies in the shape of microbes are almost exclusively sporeless micrococci.

"Regarding the course you might adopt in case you were called upon to operate under circumstances where you had no chemical antiseptic at your disposal. First, you should have your sponges well boiled, and also the fine silk threads which you will use for securing bleeding-points (the ends being cut short). Such instruments as will not be injured by the process may also be purified in the same way.

"Towels dipped in the boiled water and spread about the seat of operation will diminish the chance of contamination of the wound from surrounding objects. Then thorough cleanliness in the ordinary sense, by the free use of soap and water, must be practised for the hands of the surgeon and his assistants and for the skin of the part operated on. For sutures under these imperfect antiseptic arrangements, materials incapable of absorbing putrescible liquids, silver wire, silkworm gut, or horsehair should be used rather than sterilized silk, in order to avoid supuration in the stitch tracks.

"For dressing the wound in the absence of chemical antiseptics, dry substances such as absorbent cotton-wool or old linen (preferably boiled before use) are far better than anything kept permanently moist, like water dressing."

ON THE INTERDEPENDENCE OF SCIENCE AND THE HEALING ART, BEING THE PRESIDENTIAL ADDRESS TO THE BRITISH ASSO- CIATION FOR THE ADVANCEMENT OF SCIENCE (Liverpool, 1896. Report of the Association)

In this, Lister's last stated address upon antiseptics, he pathetically leaves the exposition to the "younger men in the practice of my beloved profession."

He acknowledges the influence of Pasteur's labors upon surgery, and especially upon his own work. He pays tribute to Metchnikoff's discoveries, and the work of Koch, von Behring and Kitasato, and the then young theory of vaccines and serums. Graciously acknowledging that the development of science had caused him and his fellow workers in surgery to change their theories and methods, he left the improvements and simplifications to be worked out by other minds.

In respect to the experiences which led to the use of the animal ligature material, he stated:

"At the same time we had the intense interest of observing in open wounds what had previously been hidden from human view, the manner in which subcutaneous injuries are repaired. Of special interest was the process by which portions of tissue killed by the violence of the accident were disposed of, as contrasted with what had till then been invariably witnessed. Dead parts had been always seen to be gradually separated from the living by an inflammatory process and thrown off as sloughs. But when protected by the antiseptic dressing from becoming putrid and therefore irritating, a structure deprived of its life caused no disturbance in its vicinity; and, on the contrary, being of a nutritious nature, it served as pabulum for the growing elements of the neighbouring living structures, and these became in due time entirely substituted for it. Even dead bone was seen to be thus replaced by living osseous tissue.

"This suggested the idea of using threads of dead animal structures for tying blood-vessels; and this was realized by means of catgut, which is made from the intestine of the sheep. If deprived of living microbes, and otherwise properly prepared, catgut answers its purpose completely; the knot holding securely, while the ligature around the vessel becomes gradually absorbed and replaced by a ring of living tissue. The threads, instead of being left long as before, could now be cut short, and the

tedious process of separation of the ligature, with its attendant serious danger of bleeding, was avoided.

"The appliances which I first used for carrying out the antiseptic principle were both rude and needlessly complicated. The years that have since passed have witnessed great improvements in both respects.

"At the London Medical Congress in 1881, I hinted, when describing the experiments I have alluded to, that it might turn out possible to disregard altogether the atmospheric dust. But greatly as I should have rejoiced at such a simplification of our procedure, if justifiable, I did not then venture to test it in practice. I knew that with the safeguards which we then employed I could ensure the safety of my patients, and I did not dare to imperil it by relaxing them. There is one golden rule for all experiments upon our fellow men. Let the thing tried be that which, according to our best judgment, is the most likely to promote the welfare of the patient. In other words, Do as you would be done by."

THE THIRD HUXLEY LECTURE, DELIVERED BEFORE THE MEDICAL SCHOOL OF CHARING CROSS HOSPITAL, ON OCTOBER 2, 1900 (*British Medical Journal*, October 6, 1900. Republished with corrections, February, 1907)

To Lister this constituted a sort of a "farewell" address. It was a summary and history of physiological and pathological work, which bore more or less directly upon the antiseptic system of surgery.

This address has been characterized as "an apology" and an explanation of his life-work.

In recording his early observations upon the suture, Lister said:

"When Marion Sims had published his remarkable success with the silver suture in gynaecology, I resolved to give it a trial in general surgery. At that time, as assistant surgeon in the Royal Infirmary of Edinburgh, I had charge of the Lock Hospital; and one of the patients having an atheromatous tumour of the scalp, I removed it and brought the edges of the skin together with a silver stitch. No vessel required ligature, and the wound healed without suppuration. As the suture created no disturbance, I left it *in situ* for about ten days, when I took the patient over to Mr. Syme and showed him the skin about

the wire perfectly pale and natural in appearance without a trace of discharge, whereas a silk stitch would within four days have infallibly caused suppuration, with surrounding redness. Mr. Syme at once recognized the importance of the facts, and from that day forward the silver suture was used for all wounds in the clinical wards, until, some years later, antiseptic measures caused it to give place to the more convenient and no longer hurtful silk.

"In thinking over this striking difference between the effects of the two kinds of suture, it seemed to me clear that it depended on the silk imbibing blood and serum, which, undergoing decomposition in its interstices, grew more irritating the longer the process continued; whereas the metal gave no hold to the organic liquids, which were shed unaltered as fast as they were effused. From these and other analogous considerations, I taught my class at that time that decomposition of the organic liquids was the essential cause of suppuration."

ON SOME POINTS IN THE HISTORY OF ANTISEPTIC SURGERY
(*Lancet*, 1908, Vol. I, p. 1815. *British Medical Journal*, 1908, Vol. I, p. 1557)

An unfinished letter to Sir Hector Cameron (written 1906), covering disputed points, and attempting to correct certain misapprehensions.

This document contains the following reference to catgut:

"In compound fracture, to which, in 1865, I first put in practice the antiseptic principle, I applied undiluted carbolic acid freely to the injured part, in order to destroy the septic microbes already present in it. The carbolic acid formed with the blood a dense chemical compound which, together with some layers of lint steeped in the acid, produced a crust that adhered firmly to the wound and the adjacent part of the skin. This crust was left in place till all danger was over. Meanwhile, in the undisturbed wound the beautiful result occurred that the material of the crust within it, and the portions of tissue which had been destroyed by the caustic, were replaced by living tissue formed at their expense.

"That dead tissue, when protected from external influences, was so disposed of, was a most important truth new to pathology; and it afterwards suggested the idea of the catgut ligature.

"In the course of some work on the preparation of catgut for surgical purposes, I observed that if a weak solution of chromic acid in water is mixed with carbolic lotion, the mixture, which is at first a pale straw colour, gradually grows very much darker during the next few hours. This fact afforded the means of estimating the quantity of carbolic acid in a watery solution. Making a mixture of equal parts of the weak chromic liquid and a five per cent. watery solution of carbolic acid to serve as a standard of comparison, and at the same time making a corresponding mixture of the chromic liquid with the carbolic solution to be tested, and ascertaining how much the standard had to be diluted in order to bring its tint down to equality with that of the mixture containing the liquid to be tested, an estimate could be formed of the amount of carbolic acid present in the latter. On going over the subject again recently, I ascertained that hair retains this remarkable power of withdrawing carbolic acid from a watery solution after all fatty matter has been removed from it by prolonged steeping in sulphuric ether."

NOTE ON THE PREPARATION OF CATGUT FOR SURGICAL PURPOSES

[*British Medical Journal*, 1908, Vol. I, p. 125]

"CATGUT used for ligatures or sutures in surgery should fulfil various conditions. It should, after soaking in water or blood-serum, be strong enough to bear any strain to which it may be subjected, and should hold perfectly when tied in a reef-knot. It must not be so rigid as it lies among the tissues as to have any chance of working its way out by mechanical irritation. Nor should it be too quickly absorbed, but should be consumed so slowly by the cells of the new tissue that grows at its expense that, in case of the ligature of an arterial trunk in its continuity, it may serve sufficiently long as a support for the substitute living thread in its embryonic condition. At the same time, it is essential that the catgut be securely aseptic when applied.

"Of the various substances which I have tried for the preparation of catgut, that which has, with one exception, most nearly approached the ideal is sulphate of chromium. The one exception is secure asepsis of the gut substance, this salt being utterly untrustworthy as a germicide; this defect is easily remedied by the addition of a little corrosive sublimate, the

powerful germicidal action of which is not prevented by the chromium sulphate.

"I was at one time discouraged from using chromium sulphate by finding that it varied extremely in quality according to the manufacturer who supplied it. Thus one sample got from a well-known firm proved quite insoluble in water.¹ But a perfectly satisfactory result was obtained by adding solution of sulphurous acid (*Pharm. Brit.*) to solution of chromic acid until the rich orange-brown of the latter has passed through grass-green to the pure blue of chromium sulphate. When this has occurred no more should be added, since free sulphurous acid produces a precipitate with bichloride of mercury, and would thus, in proportion to its amount, withdraw the germicide from solution when the two liquids are mixed. In order to make quite sure that no free sulphurous acid is present, it is well to keep a few drops of the chromic acid liquid in reserve, and add them when the blue colour has appeared, so as to restore the green tint.

"Another point that requires attention arises from the fact that the *P. B.* solution of sulphurous acid, as obtained from the chemist, is generally somewhat deficient in the amount of SO_2 , in consequence of loss by volatilization. Hence it is necessary to use a smaller quantity of water for dissolving the chromic acid than would otherwise be used; and when the proper tint has been got, add enough distilled water to bring the liquid to the requisite measure.

"The following directions for preparing what is known as chromic (or sometimes sulpho-chromic) catgut in accordance with the above conditions were given to manufacturing chemists in 1894, but have never yet been published:—

"The preparing liquid must be twenty times the weight of the catgut. So for 40 grains of catgut 800 grains of preparing liquid are required. It is made by mixing two liquids—namely, the chromium sulphate liquid and the sublimate liquid.

"The sublimate liquid is:—Corrosive sublimate 2 grains, Distilled water 320 grains.

¹ I learn from Messrs. Morson (of Elm Street, Gray's Inn Road), who have devoted a great deal of attention to this salt, that its most suitable form requires very great care in its preparation in order to avoid variation in its composition, and also that it is extremely hygroscopic, so that, unless it is very carefully preserved, water in variable amount becomes associated with it, another cause of uncertainty in its composition.

“The sublimate may be dissolved by heat, but the solution must be used cold.

“The chromium sulphate liquid is prepared thus:—Chromic acid 4 grains, Distilled water 240 grains.

“Add to this as much sulphurous acid (*P. B.* solution) as gives a green colour. If more is added the colour becomes blue, which shows that rather too much sulphurous acid has been used. It is well to reserve a few drops of the chromic-acid solution, to be added after the blue colour has just appeared and restore it to green. Then enough distilled water is added to bring the green liquid up to 480 grains. Then add the sublimate liquid.’

“The catgut is kept twenty-four hours in the preparing liquid, and is then dried on the stretch.

“N. B.—It is essential that the CrO_3 and SO_2 solutions be mixed before the HgCl_2 solution is added.

“Catgut prepared in this way remains actively antiseptic in its substance for an indefinite period, as was shown by the following experiment:

“Some slender hanks prepared three years previously, weighing 207 grains, chopped into short segments, were placed in a small mortar and treated with enough distilled water to cover them, 2,000 grains being required for the purpose. The gut was then pressed firmly with a pestle, and the same was afterwards done three times at intervals of about three hours. The gut and water were then transferred to a stoppered bottle for seventeen hours, when the liquid was poured off and filtered, being clear and almost colourless.

“The germicidal property of the infusion was carefully tested by the late Dr. Allen Macfadyen. In spite of the large amount of water used in preparing it, he found that it destroyed the *Streptococcus pyogenes* in a quarter of an hour. When diminished to half its bulk by evaporation *in vacuo* it killed *Staphylococcus pyogenes aureus* in half an hour and deprived the resisting spores of anthrax of vitality in two hours. When further reduced by one half, although the amount of the liquid was still about twice that of the catgut to which it was applied, it killed anthrax spores in an hour.

“But while the substance of the catgut is thus not only aseptic but powerfully antiseptic, its dry surface is liable to contamination by contact with septic material, and it is essential that, before being used, it be washed with some trustworthy germicidal liquid.

"My practice has been to put the catgut, like the instruments, in 1 to 20 solution of carbolic acid about a quarter of an hour before the operation is begun. Any of the catgut that remains unused upon the reel may be afterwards kept in a similar solution for any length of time without disadvantage.

"The essential precaution of purifying the surface of the catgut is, I fear, sometimes overlooked, the result being occasional suppuration attributed to defect in the ligature, while it is really the fault of the surgeon."

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LORD LISTER wrote no text-books. He at one time had in mind the issuance of a book that might clearly elucidate the antiseptic system, but this was never accomplished.

The research and experiments which formed the basis of his work covered long periods of time, but the formulation and the writing of the results were rather hastily executed, and sometimes finished only a few minutes before delivery. Some of his addresses were made from notes, to be afterwards expanded. Usually before his writings were published they were carefully corrected and revised.

Lister seemed to be in fear lest his writings would be misunderstood and misinterpreted. He was somewhat sensitive to criticism and attack. Lady Lister was his amanuensis, as well as his assistant in research.

Lister's writings, in part only, have been collected in two volumes, "The Collected Papers of Joseph Baron Lister," published by The Clarendon Press, Oxford, 1909.

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